ELEMENTARY
PRINCIPLES
OF AGRICULTURE

FERGUSON AND LEWIS
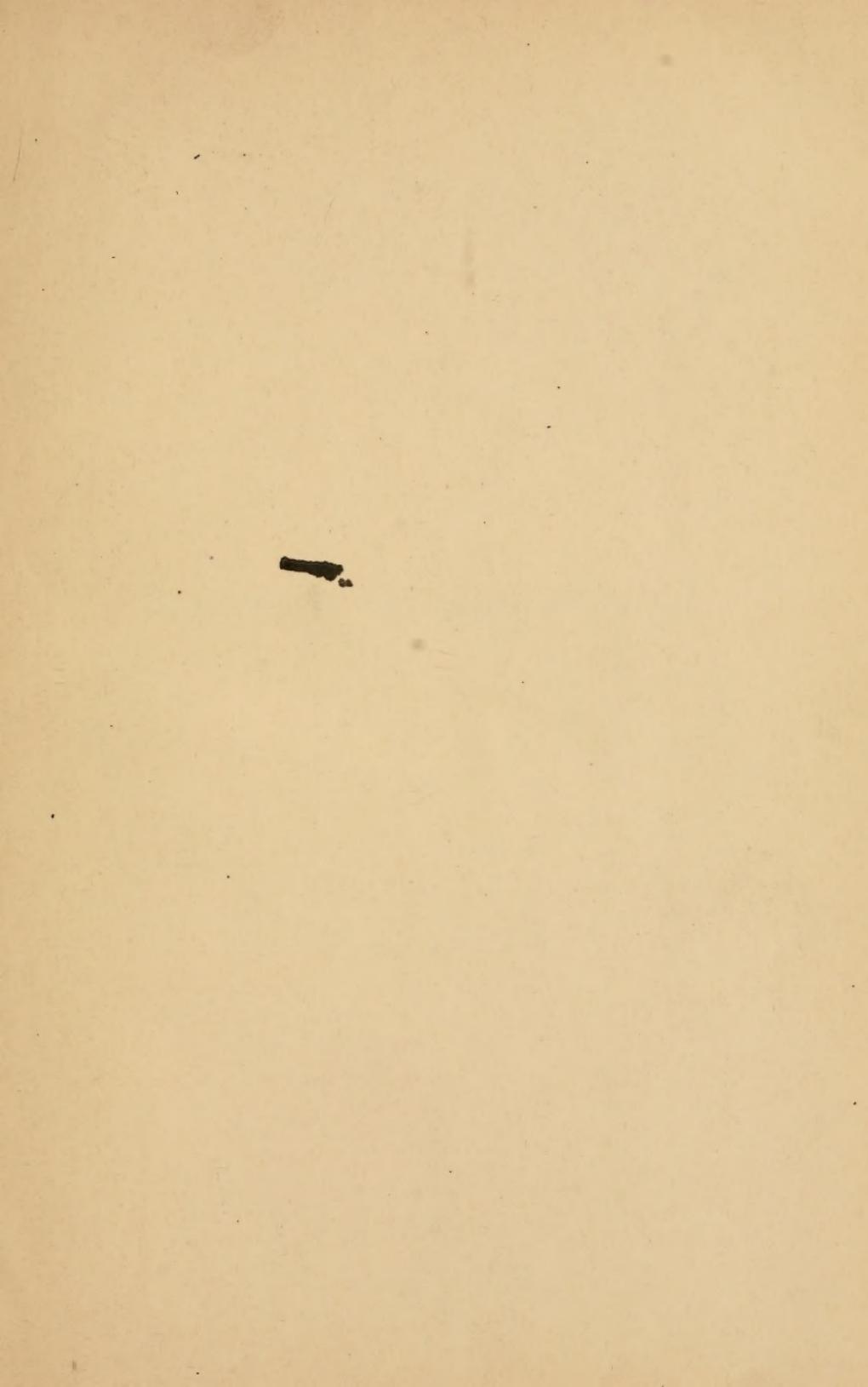
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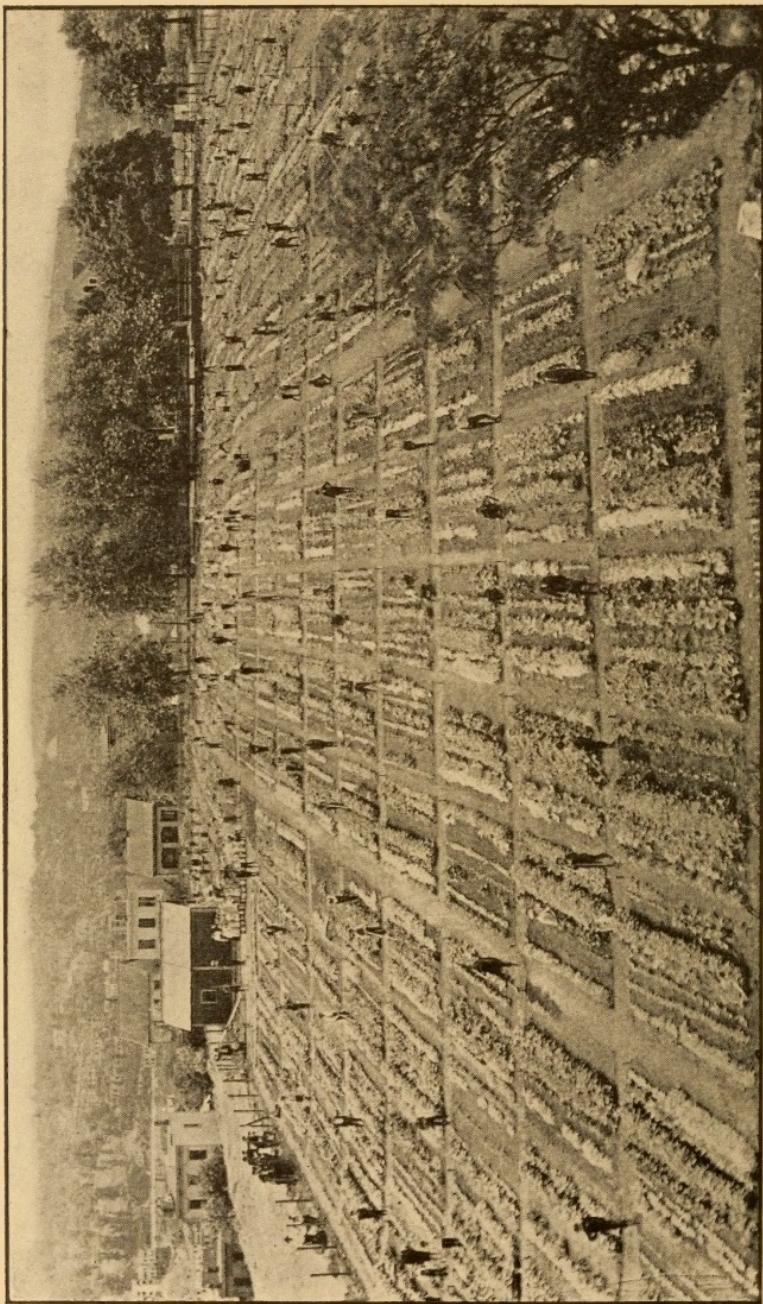
A garden school. One object of education is to train the mind to direct the hands to do useful things well.

ELEMENTARY PRINCIPLES
OF AGRICULTURE

A TEXT BOOK
FOR THE COMMON SCHOOLS

BY

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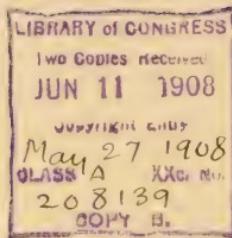
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PREFACE

THE little volume herewith submitted for the use
of the school children of the Southwest is the outcome
of many years' study of the problems of rural school
agriculture. Agriculture, as a school subject, is new,
and no guiding standards have yet been generally recog-
nized which limit the method or scope of such a text.
A careful review of the many texts that have been
published during the last ten years shows a wide range
of opinion as to the function of such texts. Some are
mere handbooks, dealing with the practical work of
agriculture; others are only a series of short chapters
on botany, chemistry, physics, zoölogy, meteorology,
etc., without reference to applications.

Our own ideas are that the primary object of a text
on agriculture, intended for the common schools, is to
satisfy the natural interest of all children about the
whys of common farm conditions. This is the first step
in developing an intelligent theory which will guide
practice.

While the idea of teaching agriculture is very old,
it is only in recent years that it has come to be a large
factor in the system of general education. A word of
introduction, therefore, may not be out of place.

A number of agricultural colleges and special schools
for agricultural instruction were established between
1840 and 1860. Some were privately endowed, others
supported out of public revenues. In 1862, a bill, known
as the "Morrill Bill," passed the National Congress,

appropriating a specified amount of the public lands for the benefit of colleges to be established in the several states and territories, in which agriculture and the mechanical arts would be taught along with the subjects usually taught in the better grade of colleges. In the course of time, all the states and territories established colleges under the provisions of this Act. To fill the professorships in the classics and sciences was an easy matter. To fill the professorships in agriculture was a problem. Agriculture had not been thought of as a field of much learning. "What is agriculture," and "What shall be taught as agriculture," were seriously discussed. It was soon discovered that while agriculture as an industry was old, little had been done to develop and organize the body of scientific facts bearing on the country's greatest industry. Something else was needed, —agricultural investigation.

Several states established agricultural experiment stations in connection with their colleges, but in 1887 Congress passed a bill authorizing the organization of an experiment station in connection with each of the agricultural colleges. These institutions have been studying agricultural problems for only a little more than a quarter of a century, and in so short a time have discovered enough facts, and arranged these facts, so that we now have a science called agricultural science.

The development of agricultural teaching has kept pace with the development of our knowledge of the subject. The teaching of agriculture is no longer confined to the colleges. The discoveries and ideas brought out by the investigations are too important to all the country not to be more generally taught. While only one-third of the population live in the country, approxi-

mately half of our people are directly interested in agriculture as a business. Why not give them the benefit of what is known about the soil, plants and animals? "If any man were to find himself in a new country, wholly devoid of schools, and were to be set the task of originating and organizing a school system, he would almost unconsciously introduce some subjects that would be related to the habits of the people and the welfare of the community." Agriculture is taught not merely because it is an important industry, but as a school subject, to be studied from the point of view of science. As a field of study and investigation, it has attracted the highest talent. Agricultural science is now developed to a plane where it takes rank with the older and more popular lines of scientific investigation, such as chemistry, physics, biology, etc.

We study language in order that we may more easily exchange ideas with our fellows; we study history and civics in order that we may better understand our social relations; we encourage the development of our artistic and emotional natures by singing, declamations, drawing, etc.; we study geography to get a knowledge of "the earth as the home of man," but not until recent years have we stopped to study the conditions that affect our immediate material environment,—the soil on which we live and grow the materials for food, shelter and raiment. It is surely no fad to study the things that are closest to us.

As a broad, general statement, it is plain that a subject so universal as agriculture should be studied, even though, as individuals, our work will be restricted to other lines. We shall still have a large interest in the ideas that belong to our country's greatest industry.

The large body of useful facts and working theory that have been worked out by our experiment stations has proven the great value of the subject. When Professor Babcock discovered a simple method of testing the value of dairy cows, he conferred a great benefit on mankind. A striking illustration of the need for a general knowledge of this test was discovered in Illinois. From investigations made by the experiment station, it was found that a large per cent of the cows on the farm dairies of Illinois did not give enough milk and butter to pay for their board; that, instead of the cows working to make a living for the farmer, the farmer was working to make a living for the cows. What is true of Illinois is true of other sections. Equally significant facts have been brought to light in other lines of farm activity.

Oklahoma is the first state to make the teaching of agriculture a constitutional requirement. The Agricultural and Mechanical College, with its Agricultural Experiment Station, and the state's system of Farmers' Institutes, the regulations dealing with fertilizer inspection, live-stock inspection, nursery inspection, and other matters affecting the interest of agriculture in Oklahoma, is controlled by the Oklahoma State Board of Agriculture.

The Board of Agriculture is selected by the farmers of the state and consists of eleven members. The president of the Board is elected by the people at a general election, and serves for four years. The remaining ten members are elected at annual meetings of the delegates from the various county farmers' institutes, held at the Agricultural and Mechanical College. After the present plan becomes fully established, there will

be two members of the Board elected at each annual meeting, and their term of service will be for five years.

It is plain that this plan places the responsibility for the successful administration of the laws framed for the upbuilding of the agricultural interests of Oklahoma upon the farmers themselves, and especially upon those participating in the county institutes.

ACKNOWLEDGEMENTS

In planning and preparing the work, we have had the benefit of counsel from a number of teachers, practical farmers, and others who are regularly engaged in the professional study of agricultural problems. The text has been greatly improved by the careful reading, either in whole or in part, by the following persons: Miss Dora Schnell, formerly of the Dallas public schools, who has very kindly prepared the questions at the end of the chapters; Miss Ada Henderson, of the public schools of Cameron, Texas; Mr. and Mrs. T. P. Robinson, both of them experienced teachers, who are also successful farmers. The above may be taken as representing the teaching and popular point of view.

On the professional and technical side, valuable assistance and criticism have been given by Prof. J. H. Connell, President of the Oklahoma A. and M. College; Prof. F. R. Marshall, late Professor of Animal Husbandry, Texas A. and M. College, but now of the University of Ohio; Prof. T. V. Munson, our most accomplished and distinguished horticulturist; Prof. W. H. Long, Professor of Biology in the North Texas Normal College; Prof. C. O. Moser, Special Agent, United States Department of Agriculture, and supervisor of the Denison Demon-

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The illustrations have been selected for their accuracy
and educational value. They have been drawn from
various sources, and to the gentlemen and firms who
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wish to extend our thanks. Many of the illustrations
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<div align="right">The Authors.</div>

TABLE OF CONTENTS

(xiii)

PART II

PART III

SPECIAL TOPICS

APPENDIX

AGRICULTURAL LITERATURE

Agriculture is older than civilization, yet it is the last large field of human endeavor to develop a literature that is distinctly its own, and the last to find a place in our system of education.

In spite of this comparative newness, our publishing houses now issue books on special and general agriculture that compare favorably with the best in other lines of thought. Every school library should have a number of the more recent special treatises on the important phases of agriculture. A suggestive list is given in Appendix A.

In addition to the volumes published by the regular book trade, the United States Department of Agriculture and the several state agricultural experiment stations publish, for free distribution, bulletins giving accounts of investigations on the varied problems of agricultural science and practice.

Special attention is called to the series of "Farmers' Bulletins," issued by the United States Department of Agriculture, Washington, D. C. They are sent to all parties on request. This series now includes a special bulletin on all the leading field, orchard and garden crops, and the many classes of farm animals.

Many states have a state department of agriculture that publish bulletins dealing with agriculture. With a few exceptions, all government publications are sent free. Application should be made to the Directors of the state experiment stations.

ELEMENTARY PRINCIPLES OF AGRICULTURE

PART I

CHAPTER I

AGRICULTURE AND KNOWLEDGE

1. Agriculture and Life. "The object of agriculture," says Professor Johnson, " is the production of certain plants and certain animals which are employed to feed, clothe, and otherwise serve the human race." Every American should understand the elementary principles of agriculture, because it is our country's most important industry. Whatever materially affects the productions of the farms and ranches also affects the trades and professions, for the latter are the chief consumers of agricultural products.

2. The Three Phases of Agriculture. There are three phases of agriculture: first, the business phase; second, the arts or crafts phase; and third, the scientific phase. Agriculture, as a means of making a living, is a business. Growing crops and stock, and the manufacturing of these raw materials into finished products, are necessary arts, based on a knowledge of the working of natural forces. The giving of milk by a cow, or the development of a peach from a flower, are natural phenomena. Increasing the flow of milk, or increasing the fruitfulness of a plant, are natural arts. Doing these things

for profit is a matter of business Knowing how these things are done, how to control the natural forces so that certain results are secured, are matters of knowledge. When all this knowledge is systematically arranged, we have a science. As it is about agriculture, it is agricultural science.

3. Natural Science is organized knowledge of the phenomena of natural objects. The soil, the plants and the animals with which the farmer works are natural objects. A knowledge of the science of the natural objects of the farm serves to guide the farmer in the practice of his craft. Knowing how plants grow is not only interesting, but also useful information to persons who grow plants. The same is true of animals. To know something of how plants grow is to have a knowledge of botany. To know how to grow plants is to have some knowledge of agriculture.

4. A Knowledge of the Science of Agriculture is desirable. Ability to work amounts to little without the application of knowledge. We may know how, or possess the skill to do a certain kind of work, without knowing the reason for doing it in that particular way. A man may guide a team and hold a plow so that it runs smoothly, and yet not know why, or when, or how to plow, to secure a desired result. Hence, we have an art of doing things, and a science of *why, when* and *how*. The master workman must possess the scientific knowledge that underlies his trade.

5. How a Knowledge of Agriculture is Gained. Knowledge comes by exact observation and correct thinking. Observations are sometimes incorrect or incomplete. As a basis for correct thinking, we must have accurate observation. Books are merely the printed statements

of what others have observed and thought. Hence, book information is not always in accord with the actual conditions; and, by placing too much confidence in the printed page, one is sometimes misled. An ancient writer stated that a cow had eight upper front teeth. For centuries afterward, this statement was believed and repeated in many books, until one more careful looked into a cow's mouth and found, not eight, but no upper front teeth. Practical farmers, teachers, and books may guide us as to how best to find out; but we must use our own hands, eyes, and minds to acquire knowledge, if we wish to really know. In writing out our observations, we must be careful to distinguish between what is *observed* and the *conclusions* which we make from our observations.

QUESTIONS

1. What is the object of Agriculture? 2. Why should Americans particularly study Agriculture? 3. What are the three phases of Agriculture? Distinguish between these by familiar examples. 4. What is a Natural Science? 5. How does Botany differ from the Science of Agriculture? 6. In what way is a knowledge of the Science of Agriculture desirable? 7. How may this knowledge be gained?

CHAPTER II

PLANTS AND THEIR FOOD

6. Environment is a general term for all the conditions that surround an animal or plant, such as air, soil, water, light, temperature, other plants or animals, etc.

7. Culture seeks to make the environment favorable to the particular plant or animal, or to produce plants and animals better adapted to the environment. The most important conditions are those that affect the supply of the substances used for food by the plant or animal. To encourage the growth of, say, a corn plant, we destroy the weeds that would injure it, and cultivate the ground to make a better home for its roots. To intelligently cultivate plants, we must first learn how plants grow and get their food.

8. Not All Plants Use the Same Kinds of Food. Not all plants are like those familiar to us, as trees, herbs, etc. Possibly we do not often think of the yeast put in the dough to make the bread " rise," or the " green scum " on the ponds, as plants,—yet they are, though very simple ones. The yeast which we get from the grocery store as " compressed yeast " is only a mass of millions of very small plants, each one composed of a tiny mass of living substance, called *protoplasm*.* This mass of protoplasm is surrounded by a delicate membrane, called a cell-wall. These plants are so small that they

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Protoplasm (meaning primitive substance) is the older term for that part of the cell having the property of life. Some writers prefer the term *bioplasm*, (meaning living substance).

can not be seen by the naked eye. When greatly magnified by the microscope, their simple structure is plainly seen. Each plant is only a single cell, such as shown in Fig. 2 *a* and *b*. Each one of these plants, or cells, has the power to form daughter plants, that soon become independent.

9. Fungi. Yeast belongs to a class of plants called fungi (fun-gi—singular, fungus). These fungus plants are very small, but they are very important. The bacteria causing the nodules on peas and clover plants are very beneficial. Some cause disease that destroys other plants, like the rust on oats, mildew on roses and grapes, or the rots of fruits and roots. Other kinds of these simple plants cause disease in animals, as cholera in swine and chickens. Their food consists of the substances of other plants, or of animals, like starch, sugars, fat, lean meat, white of egg, etc. In order to become familiar with the conditions which favor the growth of yeast-like plants, we will set up the following experiment:

Fig. 2. Yeast Colonies. *A*, surface view of full-grown plants with young branches or buds. *B*, view of similar colonies seen as though cut across. Magnified about 750 times.
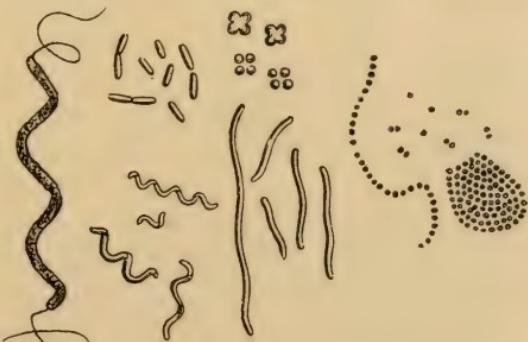
Fig. 3. Figures of various kinds of Bacteria. (After Cohn and Sachs. Very highly magnified.)

9a. Food Materials for Yeast. Secure two large bottles or fruit jars, and fill both about two-thirds full of clear well-water. To one jar add a teaspoonful of sugar and about as much of the white of an egg. See that both are completely dissolved. Now add to both jars small lumps of the ordinary "compressed yeast," or dry yeast cake, secured from the bakery. Whichever is used, see that it is well dissolved in a spoonful of water before adding to the jar. Stir well and notice that the liquids are clear, or nearly so. Set aside in a warm place, but not in strong light, and observe once or twice a day for several days. The liquid soon becomes cloudy in the jar to which the food was added, but not in the jar of water. The cloudy effects are due to the large number of yeast plants formed. The sugar and egg substance furnish the nourishment for their growth. They do not multiply in the pure water. Yeast grows in the bread dough because the dough contains all the substances needed for the nourishment of the yeast plants. In the "dry yeast" these tiny cells are in a dormant condition, like seeds.

10. The Green "Pond Scums" belong to a class of plants called algæ (singular, alga). There are many kinds, and nearly all of them are very simple, being composed of single cells, or small masses of cells. Algæ contain a green coloring matter, which yeast-like plants do not have. We shall later learn something of the value of this green coloring matter to the plant.
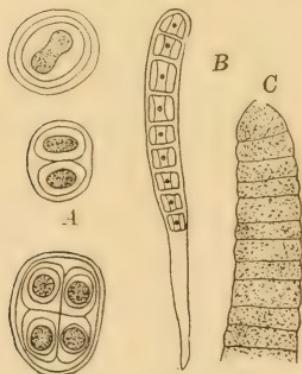
Fig. 4. Cells of Algæ. *A*, a simple one-celled form with the cells embedded in a jelly-like wall. *B* and *C*, forms with the cells arranged in chains.

11. The Food Materials of Green Plants are made from water, carbonic acid gas, and the simple minerals dissolved in the natural waters of the soil. These are combined to make all the substances necessary for the nourishment and growth of their cells. They must

have sunlight before they can make their food materials out of the simple substances named.

11a. Food Materials Used by Green Plants. Use a jar filled with clear spring water, as mentioned in 9a, but add nothing to the jar but a small bit of some common pond scum, secured from the streams or watering troughs. Place the jar in a well-lighted window, preferably a north window. Take care that the water does not get too warm by staying too long in very bright light. Observe from day to day to see if the alga mass is growing larger. It will grow much slower than the yeast plants. The jar may be kept for weeks by adding water from time to time, to make up the loss by evaporation. If the alga grows, we must conclude that it gets all the food it used from the well-water and air, because nothing else was added. The water contains salts dissolved from the soil, and carbonic acid gas dissolved from the air.

12. Green Plants, like the pond scums, herbs, trees, etc., that are able to make their food materials out of simple substances, are called "independent," or "self-feeding plants." Plants like the yeast, which must have their food substances prepared for them, are called "dependent plants."

13. Cellular Structure of Plants. The yeast and algæ are examples of very simple plants. The higher plants which we know as trees, herbs and weeds, are very large, but, if examined with a strong microscope, we find that their bodies are made up of thousands, even millions, of tiny cells, much like the cells of the algæ and
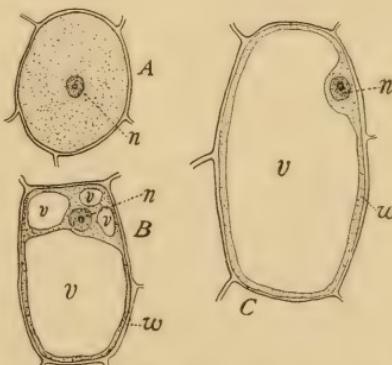

Fig. 5. Growth of individual cells. *A*, a very young cell. *B*, similar cell, but very much larger and older, showing vacuoles or sap spaces. *C*, a still later stage—all greatly magnified. *w*, cell-wall. *n*, nucleus. *v*, vacuoles.

yeast, except that their sides are flattened by pressing against each other. New cells are formed by a single cell dividing into two cells (Fig. 6). These new cells grow to a certain size and divide again, and so on till great numbers are formed. (See Fig. 14, *C*.)
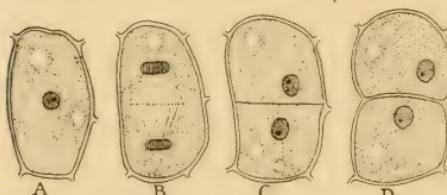

Fig. 6. In forming new cells the living substance or protoplasm divides and then a cell-wall is formed between them.

14. The Living Substances of Cells. The cell is the unit out of which all plant and animal bodies are made, just as the brick is the unit out of which buildings are made. Within each cell-wall is the living substance, called protoplasm. It differs from dead substance in that it has a different chemical constitution, and the power of self-action. Protoplasm is a clear granular substance, like the white of an egg or mucilage. It differs from these in that it has *life*.

QUESTIONS

1. Define environment. 2. What is the purpose of "culture?" 3. What is the most important condition of plant environment? 4. Describe the yeast plant. 5. Name other kinds of these simple plants, and mention their importance. 6. What do you learn from the yeast experiment as to the kind of food used by the yeast plants? 7. What is the chief difference between a fungus and an alga? 8. What do you learn from the "pond scum" experiment as to the food of the algæ? 9. Are the higher plants, such as herbs and trees, in any way similar to simple plants, such as yeast and pond scum? 10. Why are green plants called independent; fungi, dependent plants?

STRUCTURE OF SEEDS

15. Germinating Seeds. The " higher plants " have their round of life from the seed to the mature plant, forming roots, stems, branches, leaves and flowers. Many crops of the farm and garden are started each year from seed. We should observe a number of the larger kinds of seeds, such as corn, beans, peas, cotton, squash, sunflower, castor beans, and any other large seeds that may be easily secured. After we have closely examined them as to their size, texture of their coverings, and other quali-ties, a number of each kind should be planted and observed in the schoolroom while they are germi-nating. They may
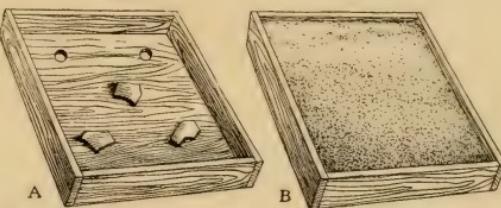
Fig. 7. Gardeners' flats. *A*, showing holes for drainage. *B*, filled with sand or loam ready for planting.

be planted out-of-doors if the weather is warm, but it will be much better to plant them in boxes of moist, clean sand or sawdust. A shallow box, 3 or 4 inches deep, like the gardener's flat (Fig. 7), will answer the purpose very well. After the seeds are planted, the box should be kept in a warm place. It may be kept covered with a pane of glass, to prevent the sand from drying out too rapidly. The student's ger-minating seeds will furnish fine study material for the class.

15a. Have the pupils make a list of all the common plants with which they are familiar that are started from seeds; also, those that are started from bulbs, roots, and cuttings.

16. Structure of Seeds. When we look at a bean, we see it is covered with a thin skin, or "seed-coat," which is quite smooth except at the edge where it was attached to the bean pod. Now, if we remove this coat from a

Fig. 8. Bean seed split open to show parts of plantlet

seed (using one that has been soaked in water over-night), two large, thick " seed leaves," or *cotyledons* (cot-y-le-dons), joined to a minute stem, may be seen. (Fig. 8.) One end of the stem is round and plump, while the other bears two tiny leaves. The latter is the stem end, and bears the young bud. The root grows from the other end. Thus we see that the bean has all the parts of a plant, but a very small or embryo plant.

17. Stored-up Food in Seeds. Plants need food to build up their bodies and provide energy, just as animals do. The cotyledons do not look like ordinary leaves, because they are filled with much starch and other substances, to nourish the plantlet when it begins to grow. Substances stored up in seeds like this are called " reserve foods." The reserve food in the case of the bean is largely starch. In some plants it is largely oil, as in cotton seed, sunflower, pecan, flax, etc. Besides starch and oils, another class of substances is present as a reserve food of all kinds of seeds, called *proteids*. Proteids from animal bodies are familiar, as the whites and yolks of eggs, clabber of milk, clot of blood, etc.

18. Corn. The corn " grain " is covered with a clear skin, or seed-coat.* If we cut through a corn grain, as shown in Fig. 9, we see a yellowish oily germ, or embryo, on one side, and a large starchy mass of additional reserve food stored back of the germ. When the reserve food is stored outside of the germ, it is called *endosperm*. The endosperm in the corn grain exists in two layers, one of which is starchy and loose, and the other clear and hard.

Fig. 9. Section of a grain of corn showing the parts of the germ or embryo corn plant (*A*, *B* and *E*), and position of reserve food *A*, root end and *B* shoot end of embryo; *E*, the part of the embryo that absorbs the reserve food during germination; *C*, soft starch; *D*, horny part of reserve food.

19. Cotton. In cotton, the seed-coat is covered with a layer of fibers, or lint. The hard brownish coat encloses an embryo cotton plant, with leaves closely rolled around the stem. The parts are best made out in seeds that have just germinated. Cotton seeds are very rich in oils and proteids.

QUESTIONS

1. In what other ways than by seeds may plants start new individuals? 2. Name the parts of a plant that are enclosed in a bean seed. Describe them as they are in the seed. 3. Of what use are the cotyledons? 4. What is meant by reserve food? 5. What substances may be present in reserve foods? 6. Describe the corn seed. 7. What is the essential difference between the bean seed and the corn seed? 8. Describe the cotton seed. 9. Is it most like the corn seed, or the bean seed? that is, in what part of the seed is the reserve food stored?

*In reality, the covering of a grain of corn is double, but the two coats are so closely united that it is difficult to distinguish them without special preparation. The outer coat corresponds to the pod, or seed-case, as in beans.

HOW SEEDLINGS GET ESTABLISHED

20. Germination. Germinating seeds must have water, air, and a certain amount of warmth. The prompt-ness of germination depends on how well these conditions are provided. In three or four days, seeds sown in moist sand will be found to be very much larger. They have absorbed water from the sand, so much so that the weight of the seed is now much greater than when it was dry. In some, the coverings of the seed will be found broken, and tiny roots pushing through. If they are watched for some days, it will be found that this tiny root grows in a downward direction, regardless of the position of the seed. The root makes a con-siderable growth before the young stem, with its tiny leaves, gets out of the seed case. (Fig. 10.) When the embryo plant inside the case begins to grow, we say the seed is *germinating*.
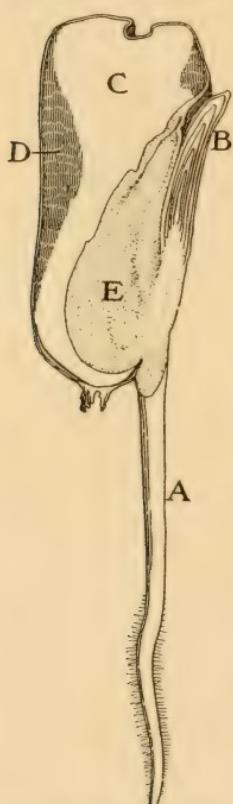

Fig. 10. During the early stages of germination the root grows faster than the shoot. *A*, root. *B*, shoot. *C*, starchy endosperm. *D*, horny endosperm.

21. Root-hairs. The tiny rootlets which we found pushing through the seed coat are just like the thousands of branches found on roots of

older plants. They are very delicate, and it is better to grow the roots in moist air, to see the many minute root-hairs. On a seedling with root-lets an inch or more long, notice that just back of the tip it is covered with a very fine fuzzy growth. This fuzzy growth is composed of thou-sands of slender tube-like cells, called root-hairs. (Figs. 11 and 12.)

They are formed near the root's tip. After a time they die. They cannot be found on the root except for a short way from the tip. Unless the soil is very carefully washed from the rootlets, the root-hairs may not been seen. (Fig. 11, B.)

22. How the Root Absorbs Water. Even though the seedlings that have been growing in sand or sawdust be

Fig. 11. Seedlings of mustard. *A*, with particles of soil cling-ing to root-hairs. *B*, after removal of soil by a stream of water. After Sachs.

very carefully washed, much of the sand or sawdust adheres to the hairs. (Fig. 12.) The root-hairs hold the soil
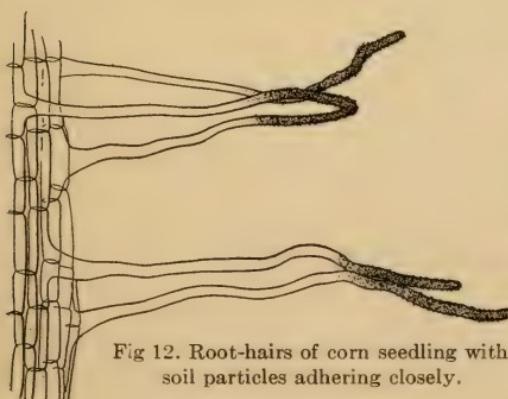
Fig 12. Root-hairs of corn seedling with soil particles adhering closely.

particles to the root. When the roots are growing in moist air, they are straight; but in the soil the hairs apply them-selves very closely to the soil parti-cles. (Fig. 13.) The water ab-

sorbed by the root is first taken in by the root-hairs. The seedlings may be growing in soil so dry that water may not be pressed out of it, still, the soil particles are covered with a film of moisture from which the roots absorb their supply. (See Fig. 40.)

23. How the Root Grows. The root grows only at the tip. The tip does not grow straight through the soil.

Fig. 13. Diagram of a portion of soil penetrated by root-hairs, *h, h'*, arising from root, *e*. At *z, s, s'* the hair has grown into contact with some of the soil particles, T, which are surrounded by water films (shaded by parallel lines). After Sachs.

but bends to and fro in a sort of circle, taking advantage of the small openings between the soil particles. It is covered with a delicate *root-cap.* As the root lengthens, the cells of the cap are rubbed off, but new ones are formed to take their place. Only the region in front of the root-hairs has the power of lengthening. (Fig. 14.)

24. Absorption of Water by Seeds. Seeds absorb water from the soil particles. When dry seeds are placed in a bed of moist sand or loam, the little film of moisture that covers the soil particles is absorbed by the seeds.

Seeds will not absorb enough water from moist air to make them germinate. They must be in contact with a film of water.

24a. The Swelling of Seeds. Place some common beans in a glass of water, and observe every few minutes. Where does the seed coat wrinkle first?

24b. Rate of Absorption Affected by the Amount of Water Present. Place a dozen seeds in a glass of water, a second dozen in wet sand, and a third dozen in slightly damp sand. Examine every day, and judge the amount of water absorbed, by the increased size and weight of the seeds.

24c. Rate of Absorption Affected by the Number of Points of Contact. Take two lots of seeds, corn for example, and place each lot in a tumbler or other vessel with the same amount of moist sawdust. In one, sprinkle a layer of

Fig. 14. *A*, a young root of the pea marked with fine lines of waterproof ink into 13 spaces. *B*, the same root, 24 hours later, showing elongation only in terminal 5 spaces. The rate of growth is greatest in the second and third spaces and slow in the first, fourth and fifth. Magnified 2 diam; *C*, tip of root greatly magnified and shown in section. *w*, root-cap; *i*, younger part of cap; *i*, dead cells separating from cap; *s*, growing point; *p*, central cylinder.

sawdust, and then a layer of seeds, then another layer of each, taking care that in one the saw-dust is not pressed down, but kept very loose. Prepare the second vessel just as above, but press the sawdust firmly around the seeds. This increases the number of points of contact between the sawdust and the seeds. Cover, to prevent drying out, and examine the seeds at the end of every twelve hours. Does pressing the saw-dust about the seeds make them swell more quickly?

24d. Prompt Absorption Hastens Germination. Sow some peas in a gardener's flat, filled with very loose sawdust. Press the sawdust

down firmly on one end and leave loose on the other. Cover with a glass, to prevent drying out, and note the time required for germination in the two ends.

25. Other Conditions affecting the rate of absorption of water by the seeds, are temperature, the nature of the seed-coat, etc. The seed covering of most cultivated plants will absorb and transmit the soil-water quite freely, though many seeds are provided with thick, bony shells, or coats, that resist the action of water for weeks, even months, if they once become dry. Such seeds are the peach, locust, walnuts, and most wild seeds. Germination may sometimes be hastened in such seeds by soaking in warm water before planting; freezing while moist aids and hastens others, especially those having thick, hard shells, such as peach, walnut, hickory, plum, etc.

26. How Warmth Affects Germination. A certain degree of warmth is necessary before seeds will germinate. If we had placed in a refrigerator the seeds used in the experiment described in ¶ 15, the corn and beans would not have germinated, although they had plenty of water and air. This shows that a certain amount of warmth is necessary for germination. Some seeds, however, will germinate at a very low temperature, though they do not germinate quickly. The lowest temperature at which seeds will germinate is called the '' minimum germination temperature.'' The highest temperature at which they can germinate and live is called the '' maximum germination temperature.'' Between the highest and the lowest there is a temperature at which germination takes place quickly, but without injury to the seedlings. This is called the '' optimum germination temperature.'' These temperatures have

been determined by trial for many kinds of seeds. The following results were reported by the celebrated German botanist, Julius Sachs:*

EFFECT OF TEMPERATURE ON GERMINATION

Kind of Seeds	Minimum or lowest between	Optimum or best between	Maximum or highest between
	Fahr.	Fahr.	Fahr.
Oats................	32– 41°	77– 88°	88– 99°
Pea	32– 41°	77– 88°	88– 99°
Wheat..............	32– 41°	77– 88°	88–108°
Indian Corn........	41– 51°	99–111°	111–122°
Sunflower..........	41– 51°	88– 99°	99–111°
Pumpkin...........	51– 61°	93–111°	111–122°
Melon.............	60– 65°	88– 99°	111–122°
Alfalfa............	99–111°	99–111°	111–122°

27. The Soil Should Be Warm before seeds are planted. If the soil is cold, or has a temperature just above the minimum temperature, germination will be slow, and many seeds will rot before the seedling is established. The soil should be considerably above the minimum temperature before seeds are planted. The variation in the minimum temperature required for germination in different kinds of seeds explains why some seeds can be planted much earlier than others.

28. Effect of Temperature on the Promptness of Germination. In some tests made by Professor Haberlandt, it was found that the seeds of most of the small grain crops required five to seven days to begin germination at 41° Fahr., while at 51° Fahr. only half the time was required. At 65° Fahr., one day was sufficient

*Julius Sachs, esteemed as the founder of modern plant physiology, was born in Breslau, 1832, and died in 1897. The great interest aroused by the results of his investigations on plant nutrition led to the establishment of one of the first public institutions for the scientific study of agricultural problems

B

for wheat, rye and oats. Corn required three days, and tobacco six days. Sugar beets germinated in twenty-two days when the temperature was 41° Fahr., while, at 65° Fahr., germination commenced on the third day. (See ¶ 94, Temperature of Soils.)

29. Germinating Seeds Need Air. Growing plants, including germinating seeds, must have air. They use the oxygen of the air, and we call it *respiration*, just as we do in animals. While plants do not have lungs, they absorb the oxygen of the air and give off carbon dioxid. (But see ¶ 48, Carbon Assimilation.)

29a. To show that germinating seeds use the oxygen of the air, take two large fruit jars with good rubber bands. Into one put nothing. Into the other put a big handful of soaked seeds of corn or peas. Screw the tops on tightly and let stand for about twelve hours. Then carefully remove the top from the empty jar and thrust a lighted splinter down to near the bottom of the jar, noting the duration and brilliancy of the burning taper. The taper goes out after a time, because the burning of the wood uses up the oxygen in the jar. Now thrust a lighted paper into the jar with the germinating seeds, noting if it burns as brightly as in the empty jar. It goes out quickly because the germinating seeds have used up all the oxygen, and that carbon dioxid is present may be proven by lime water poured down the side of each jar. The empty one gives no result, while the other will show a white band on the inside of the jar. This is the test for carbon dioxid.*

30. Not All Seeds Germinate. Seeds often fail to germinate when given the proper conditions for germination. This may be due to one or more causes. They may be too old; they may have been gathered when immature; they may have become too dry, or frozen when not sufficiently dry. Sometimes they become

*Carbon dioxid, exhaled from the lungs of animals and by germinating seeds, is a gas formed by the union of two elements—carbon and oxygen. Oxygen is a gas forming a large part of the air; carbon is a solid familiar as charcoal, which is crude carbon.

damp and spoiled by molds. In many cases, insects injure them while stored. It is not usually possible to tell if seeds will germinate by looking at them.

31. Testing Seeds for Germinating Powers. If there is reason to think that a particular lot of seeds are not practically sound, they should be tested. It is a simple matter to test the germinating power of a sample of seeds. Several forms of seed-testing apparatus may be easily provided. Any arrangement will do that will allow us to place a counted number of seeds under the proper conditions for germination. Small seeds may be placed between moistened layers of clean cloth or soft paper. It is best to wash the cloth in boiling water before use, in order to lessen the liability to the growth of molds. Moist sand or sawdust is very satisfac-

Fig. 15. A good seed tester. Clean sand and soup-plates

tory for large seeds like corn, beans, etc. We will later learn more about testing seeds for yielding power.

31a. Farmer B bought two bushels of alfalfa seed at $9 per bushel, of which 95 per cent were viable, that is, capable of germinating. He was offered seed for $8 per bushel, of which only 75 per cent would germinate. What was the actual cost of a bushel of live seed in each lot?

32. How Deep Should Seeds be Planted? Seeds should be planted just deep enough to secure the conditions necessary for germination. The soil is warmer near the

Fig. 16. Seed-testing devices

surface, but also dryer. If planted too deep, it will take a longer time to begin germination, because the deeper ground is colder, particularly so in early spring. The seedling will be more exhausted before it reaches the surface if planted too deep. The seedling stage is a delicate one. Success, therefore, in getting a good stand will often depend on how well the soil has been prepared for the seeds. The soil intended for the seeds should be warm, moist and mellow. The particles should be so fine that the seed will be in contact with grains of soil on all sides. Small seeds, like tobacco, are merely pressed into the surface with a board. With such small seeds, special arrangements should be made to keep the surface from drying out.
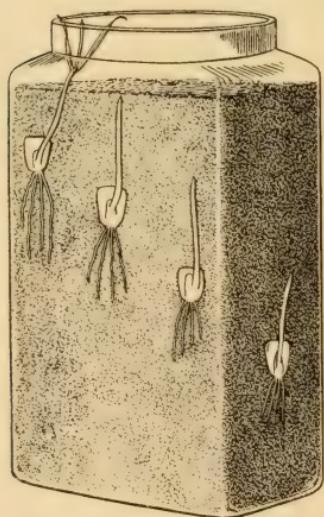
Fig. 17. An easy way to observe the effect of planting seeds at different depths.

33. In Planting Field Seeds, it is often desirable to put them sufficiently deep to allow for some drying out of the surface soil. If planted very near the surface, hot winds will often dry the soil before the seeds absorb enough water to germinate. In such dry spells it is sometimes desirable to compact the surface by rolling. This puts the surface particles in closer contact with the seeds, and the moisture is

absorbed more rapidly. In dry times the seeds often germinate more quickly in the tracks made by persons walking across the field. Gardeners often pack the surface with a spade or board or roller, after sowing the seeds. When moisture is scarce in the soil, as is quite often the case at the planting time of field seeds, a most practical and successful way to secure the germination of seeds in drills is to make the laying-off plow or tool cut a deep V-shaped furrow in the compact soil, into which the seeds are dropped and covered to the proper depth with fine soil. This V-shaped furrow affords two banks of undisturbed soil holding a supply of moisture for the seed. (Fig. 18.)

Fig. 18. Planting seeds in the "water furrow" insures a more even supply of moisture.

34. Prompt Germination Important. Seeds that germinate quickly give more vigorous plants. Besides, seeds in the ground may be destroyed by insects, or caused to rot by fungi and bacteria, or rains may come and make a hard crust on the surface through which they cannot grow. Vigorous-growing weeds may crowd out slow-growing seedlings. Prompt germination may be secured under field conditions by thoroughly preparing the seed bed, and delaying planting until the soil is warmed sufficiently for the kind of seed to be planted.

35. Time Required to Complete Germination. The plantlets are nourished for a time by the reserve food in the seed. While the plantlet is dependent on this reserve food, it is called a "seedling." The root develops faster at first, with the result that the plantlet secures

a more permanent supply of moisture from the deeper
layers. The roots grow down or downward, and the
stem and leaves grow upward into the air. The time
required for the completion of the seedling stage will
vary with the kind of seed and the conditions which
affect germination. When conditions favor quick ger-
mination and rapid growth, the supply of reserve food
is used up much sooner. Wheat seedlings will exhaust
their reserve food in ten days in warm weather; but, if
the temperature is low, it may be forty days before the
plantlet is thoroughly established.

The table below shows the effect on the time in
coming up, of planting wheat at different depths, and
the number of seedlings that grew.

Depth	Time in coming up	Proportion of seed that grew
$\frac{1}{2}$ inch	11 days	$\frac{7}{8}$
1 inch	12 days	all
2 inches	18 days	$\frac{7}{8}$
3 inches	20 days	$\frac{3}{4}$
4 inches	21 days	$\frac{1}{2}$
5 inches	22 days	$\frac{3}{8}$
6 inches	23 days	$\frac{1}{3}$

36. Hotbeds. It is often desirable to grow seedlings
under artificial conditions, so that the plants may be
ready for transplanting when the warm season comes.
Many tender garden plants, such as tomatoes and cab-
bages, are propagated in this way. Coldframes and hot-
beds are often used. A coldframe is an inclosed bed of
soil that may be covered at night to protect from frost.
A hotbed is an inclosed bed of soil, covered with glass.
as shown in Fig. 19, which is warmed by the heat of
fermenting compost placed below the bed of soil. Some-
times steam pipes are run below the seed-bed to supply
the warmth.

QUESTIONS

1. Describe germination. 2. What are root-hairs? 3. What is their position on the roots? 4. What is the purpose of root-hairs? 5. At what place does the root grow? 6. How is this growing region protected? 7. What are the conditions necessary for germination? 8. Does the air contain enough moisture for germination? 9. Name some seeds whose seed-coats hinder quick germination. 10. How may this hindrance be overcome? 11. Why do not most seeds germinate in winter? 12. What is meant by "minimum germination temperature"? By "maximum germination temperature"? By "optimum"? 13. Discuss the relation of soil, and the time of planting, to these temperatures. 14. Give in substance Professor Haberlandt's experiment in regard to the effect of temperature on the promptness of germination. 15. What necessary food does the plant get from the air? Does the plant breathe in the same gas that we do? 16. Name some of the causes of failure in germination. 17. What are some of the conditions of successful seed-planting? 18. What are coldframes? hotbeds?
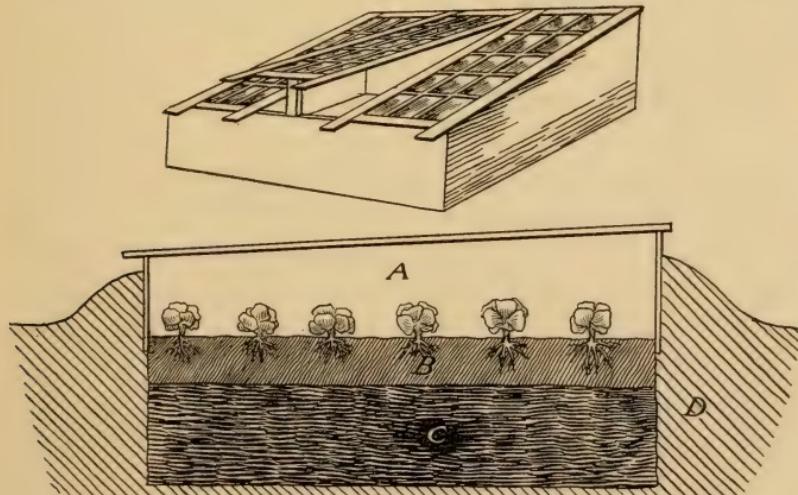

Fig. 19. Hotbeds and coldframes. The upper figure is a coldframe. If let down into the soil and warmed by fermenting compost, it is called a hotbed. *A*, Warm air; *B*, garden loam; *C*, fermenting compost; *D*, bank of soil.

PLANT SUBSTANCE

37. The Body of a Plant, including stem, root, seeds, etc., is composed chiefly of framework material and reserve food. The framework material is never used by the plant for any other purpose. The reserve food contains a variety of substances. Sometimes this reserve food is separated by mechanical means in an almost pure condition, such as starch from corn and potatoes, cooking oil from cotton seed, linseed oil from flax seed, castor oil from castor beans, corn oil from corn, and peanut butter (a thick oil) from peanuts. When the starches and oils are thus removed, there still remain the bran and meal, which contain a variety of food substances.

38. In Germinating Seeds, all the reserve food may be used to nourish the young plant. The substances in the thick cotyledons of the bean were seen to wither away as the seedling grew. The store of food for the young plant in the seed was put there by the parent plant. A corn grain will produce from one thousand to two thousand seeds and a large stalk. Where does the seedling get all the food materials to nourish so large a stalk, and lay up a large store for so many other seeds? Before we answer this question, we will try to find out something of the nature of the substances in plants.

39. Composition of Plant Substance. Chemists have ways of separating the various substances found in

plants. They find that every plant contains a variety of substances, though the quantity and number vary in different kinds of plants. Some plants, as corn, contain much starch in their seeds, and but little in the stalk. Some plants have a large amount of sugar, as beets and sugar-cane, while others contain oil. These substances which we call starch, oils, sugars, proteids, resins, gums, acids, etc., are themselves compounds of a number of "elements." The carbon mentioned in ¶ 29 is an element. So are iron, sulphur, lead and the oxygen of the air.

40. Compounds of Elements. A simple element is a substance of a peculiar kind that cannot be reduced by analysis to any simpler state. When wood burns, the carbon (an element) of the wood combines with the oxygen (an element) of the air, to form an invisible gas, known as carbon dioxid (a compound). When iron " rusts," it has formed a compound with the oxygen of the air. In germinating seeds, the oxygen absorbed is afterward given off as carbon dioxid. Oxygen combines with another element which we call hydrogen, to form the substance we call water. Thus we see that the same element may combine with a number of other elements, making a different compound or substance with each combination.

41. Substances Found in Plants are usually complex compounds of the simple elements; for instance, starch is a combination of carbon, oxygen and hydrogen, and the properties of the substance we call starch are different from any of its parts. Sugar is composed of these same elements, but has them combined in a different way. Wood is composed of the same three elements, yet combined in still a different way.

42. Protoplasm, or living substance, has the power to combine simple compounds to form the complex ones that compose the plant or animal body. Living green plants absorb water and mineral matter from the soil and carbon dioxid from the air, and with these form the complex plant substances. Light is needed by the leaves in making these combinations.

43. Elements Necessary for Plant Growth. There are about eighty different elements known, but only about a dozen are actually used by plants. The following elements are necessary for the healthy growth of plants: (1) *Carbon*, absorbed by the leaves from the air as carbon dioxid; (2) *oxygen* and (3) *hydrogen* taken in as water; and the following, all taken in by the roots from the soil solutions as soluble salts: (4) nitrogen, (5) phosphorus, (6) potassium, (7) calcium, (8) magnesium, (9) sulphur, (10) iron, and (11) chlorine. Other elements are often found in plants, but only the ones named above are really essential. If any one of these essential elements is withheld from the plant, the normal growth is impaired. The importance of the mineral substances to the welfare of plants will be discussed later. (See Chapters XII and XIII.)

44. Non-essential Elements in Plants. Besides the essential elements named, plants usually contain other elements that are really not necessary for their normal growth. The most common ones are sodium (the principal element in common salt), and silicon, a constituent of sand.

45. The Amounts of the Elements in the Plant Body. About half of the plant substance is carbon. It is a part of practically all compounds found in plants. Oxygen and hydrogen, too, are parts of nearly all

substances in plant and animal bodies. Nitrogen is always present in the living substance, or protoplasm. The other elements, usually called the " mineral elements," while absolutely essential, occur only in small amounts, usually less than five per cent. These elements form the "ash," when plants are burned.

QUESTIONS

1. Name some of the reserve food substances. 2. What is meant by a "chemical element"? Name some common ones. 3. Do plants contain simple elements? Name three plant materials that contain the same elements combined differently. 4. By what means does the plant manufacture complex compounds out of simple compounds? 5. Name the elements essential for plant growth. 6. Name the most common non-essential elements in plants. 7. What are the proportions of the elements in plants?

CHAPTER VI

HOW THE PLANT INCREASES ITS SUBSTANCE

46. The Work of Leaves. The leaves are the food factory of the plant. Perhaps you have never thought to ask why most leaves are flat. You will find a suggestion of the answer if you note that their flat faces are usually turned toward the source of the strongest light. Look at a tree, to note the position of the leaves, as seen from a distance and from among the branches. This position is an advantage to the leaf in carrying on its work, because it secures the greatest amount of energy from the sunlight for the food-making process.

**47. Structure of Leaves.** A thin section of a leaf, when examined under a powerful microscope, is seen
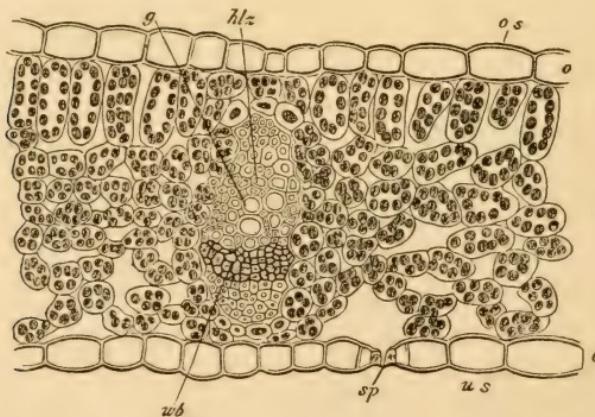
Fig. 20. Cross-section of a leaf through a "vein," or fibro-vascular bundle. *Os*, upper surface; *us*, under surface; *o*, layer of outside cells forming the epidermis; *sp*, Stoma; *g*, water duct; *wb*, phloem; *hlz*, wood of fibrovascular bundle.

to be composed of a great number of cells. The surface layer forms a skin, or "epidermis," which keeps the cells within from drying. (Fig. 20.) The epidermis is in two layers. The outer, or cutin layer, is only a thin membrane which, while transparent, to allow the light to reach the inner tissues of the leaf, is impervious to water. The second layer is a tier of cells which support the cutin layer. This epidermis is very efficient in keeping the water in the leaf. On the lower side of the leaf, and on both sides of some leaves, there are many small openings, to let the carbon dioxid enter and the excess of oxygen pass out

CHLOROPHYLL

STARCH

CARBON DIOXID
FROM THE AIR

COTYLEDONS

WATER FROM THE SOIL
(CONTAINS MINERAL FOOD)
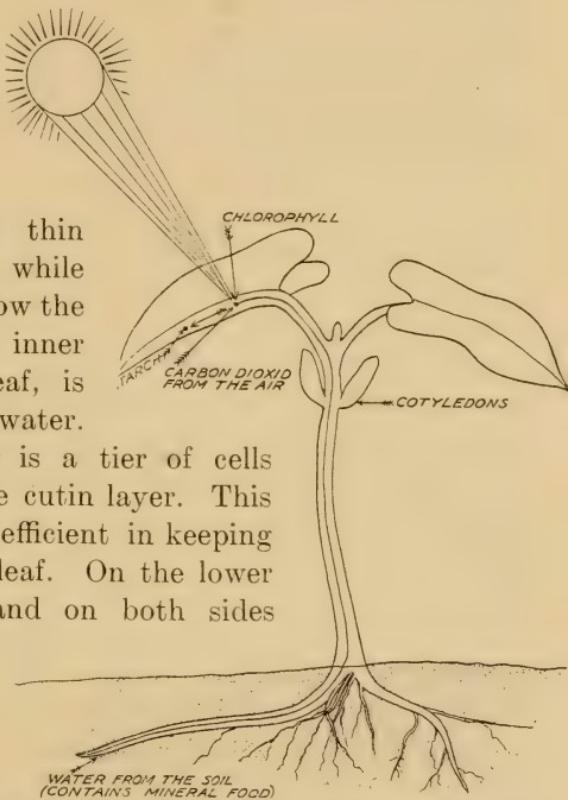
Fig. 21. How the young plant gets its food. In the early stages it is nourished from the store of food in the cotyledons. When the green leaves unfold to the light they absorb the energy of the sunlight and cause the water to combine with the carbon dioxid of the air to form starches and other foods.

when the plant is making food. (Fig. 21.) Some water escapes through these openings, or *stomata* (singular, *stoma*); but at night, when the food-making processes are not going on, these stomata close up, so that much less water escapes.

47a. To get an idea of how well the epidermis protects the

plant, take an apple or potato and peel off the epidermis and place in an exposed place beside an unpeeled specimen. Note how quickly the peeled specimen will shrivel and dry, while the other retains its form.

48. Carbon Assimilation. The soft tissue between the upper and the lower epidermis is the real food factory of the plant. It is composed of several layers of cells, all arranged sponge-like, so that the carbon dioxid of the air can reach every cell. All these cells contain minute green bodies, called chloroplastids (chlo-ro-plast-ids). The green coloring matter in these bodies is formed only in the light. It does not form in leaves growing in the dark. The yellowish stems of potatoes growing in dark cellars is a familiar example. The green color will disappear if plants are kept from the light. Advantage is taken of this property in "blanching" celery. When the light shines on the leaves, the chlorophyll absorbs the energy of the sun's rays and forms the starches, sugars, etc., from the water and carbon dioxid. This process goes on through all daylight hours. (1) *Light,* (2) *living cell with* (3) *chlorophyll,* (4) *water and* (5) *carbon dioxid must all be present.* This explains why plants do not grow unless they get plenty of sunlight. This process of making plant substance under the influence of sunlight is called "carbon assimilation." It is not confined to the leaves, but takes place in any green cell when the other conditions exist. (See Figs. 20 and 21.)

49. How Green Plants Purify the Air. When carbon dioxid combines with water, the excess of free oxygen of the carbon compound escapes into the air. By this means, growing green plants purify the air. They take up the carbon dioxid given off from the lungs, or that

formed by burning of plant or animal bodies, and retain the carbon, the oxygen being set free. But this oxygenizing power of plants is much less than is generally supposed; for the respiratory processes of plants, giving out carbon dioxid partially counteracts the effect of the assimilative process. Carbon assimilation does not take place rapidly in a subdued light, such as exists in an inclosed room.

50. Importance of Carbon Assimilation. With one or two minor exceptions, this process of food-making is the only known means of increasing the supply of food for both plants and animals. We can now answer the question asked in ¶ 38. By this process the corn plant is able to reproduce itself many fold and, also, " tall oaks from little acorns grow." No animal has this power to form food substances from the simpler compounds. It is plain, therefore, that the farmer's stock, and indeed all life, is dependent upon plant life for food. More than one-half of everything grown on the farm is carbon drawn from the air.

QUESTIONS

1. Why are most leaves flat? 2. Describe the layers in a leaf. 3. Which layer manufactures food? 4. Describe carefully how the carbon of the air gets into the leaf. 5. Is light necessary for the formation of the green color in leaves? 6. What is the effect of continued darkness on green plants? 7. Name the five necessary conditions for the making of plant substance. 8. Discuss the importance of food-making by plants.

THE WATER IN PLANTS

51. Why Plants Need Water. Plants use water in three essential ways: (1) It combines directly with carbon dioxid to form plant substance; (2) it acts as a solvent for the minerals absorbed from the soil; (3) it serves to make the plant rigid. Young, succulent stems are dependent on water for their rigidity. If water escapes, they wilt and lose the power of carrying on their work. Water is necessary for plants in other ways. It is present in all parts.

52. The Movement of Water within the Plant. There are special channels for conducting the water from the roots to the stems and leaves. The water is absorbed by the roots and is transported in special water-conducting vessels through the stem and leaves. These channels may be easily marked by placing the soft stem of some plant in a glass of blueing or of diluted red ink. The coloring matter will be carried along with the water and the path through which it moves will be shown. This experiment should be made and closely observed by all. Cut cross-sections of the stem to notice the channels through which the water travels. Leafy stems of balsam, begonia, Johnson grass, poke-berry, and other common plants, make good illustrations.

53. The Amount of Water in Plant Substance is considerable, as may be seen from the following table showing the approximate amount of water in a number of common plants.

APPROXIMATE AMOUNT OF WATER IN PLANTS

	In fresh plants— water in 100 lbs.	In air-dry plants— water in 100 lbs.
	Average	Average
Alfalfa	72	8.4
Prairie Hay..............	70	30.0
Corn Stalks..............	82	34.0
Potato Tubers	75	. . . .
Corn Grain	. . . .	10.0
Turnips	91	. . . .
Grain straw..............	. . . .	9.0
Small grains	. . . .	9 to 12

53a. How many pounds of water in a ton of freshly cut alfalfa? How many pounds of water in a ton of air-dry, or cured alfalfa?

54. Loss of Water by Plants. Plants lose water through the stomata in their leaves, and their other parts to a slight extent. Some plants lose water very slowly, even under very dry conditions, as, for instance, the cactus on the dry, open prairies. It has been estimated that ordinary cultivated plants lose water by transpiration about one-fifth to one-tenth as fast as it would evaporate from a surface of free water. In times of drought, when the air is very dry, transpiration will be greater than under ordinary conditions. Hot, dry winds increase the rate at which water escapes from the plant. (See ¶ 98, How Plants Dry the Soil.)

55. Drought-resistant Varieties of cultivated plants have coverings that prevent the ready escape of water. This may be seen in the varieties of corn imported from dry countries, which have thicker leaves and coarser shucks than the native kinds.

QUESTIONS

1. In what three ways do plants use water? 2. How does the plant get water? 3. How does the plant lose water? 4. How do drought-resisting plants prevent the escape of water?

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CHAPTER VIII

STRUCTURE AND WORK OF STEMS

56. The Primary Use of the Stem is to hold the leaves up where they may be fully exposed to the light. Sunlight furnishes the energy for the food-making work. Of course, when the leaves are more exposed to the light and winds, evaporation is increased. Therefore, stemmed plants need more water than stemless ones.

57. The Growing Point of the Stem is in the bud at the end. The cells at the growing tip are very small and delicate. The young sections, or internodes,* grow in length, forming the stem. The stem lengthens by the multiplication and growth of the cells. All the cells are much alike at first, but, as the cells lengthen, so does the stem. Many changes take place. Soon there are several kinds of cells and vessels, as shown in Fig. 22. Some are elongated,
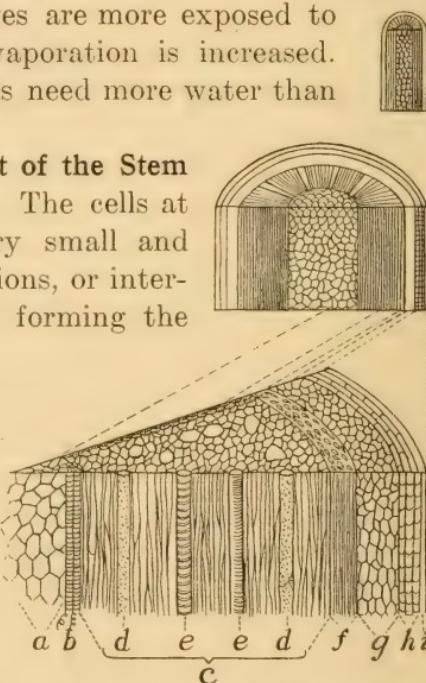
Fig. 22. Cross-section of a woody stem. Upper one actual size. *a*, pith; *b*, *d* and *e*, water ducts; *c*, woody portion; *f*, phloem; *g*, *h*, and *i*, outer protective layers. After Goodale.

*The use of the words *nodes* and *internodes* is made necessary by the double use of the word "joint."

thick-walled, woody fibers, arranged with overlapping ends cemented together, thus stiffening the stem. The water-conducting vessels are surrounded by these woody fibers. In some grasses and grass-like plants, the water vessels and wood fibers are united into strands forming the "threads," or fibro - vascular bundles, embedded in a mass of soft pithy tissue. This condition is well illustrated in the stalks of corn. The strands (Fig. 23) in the pith are bundles of woody fibers surrounding the water-conducting channels. Plants having the veins of the leaves arranged like a net have the water-conducting vessels in the woody part. (Fig. 22.) In young stems they exist as separate

Fig. 23. Corn-stalk, showing fibro- vascular bundles, or "threads."
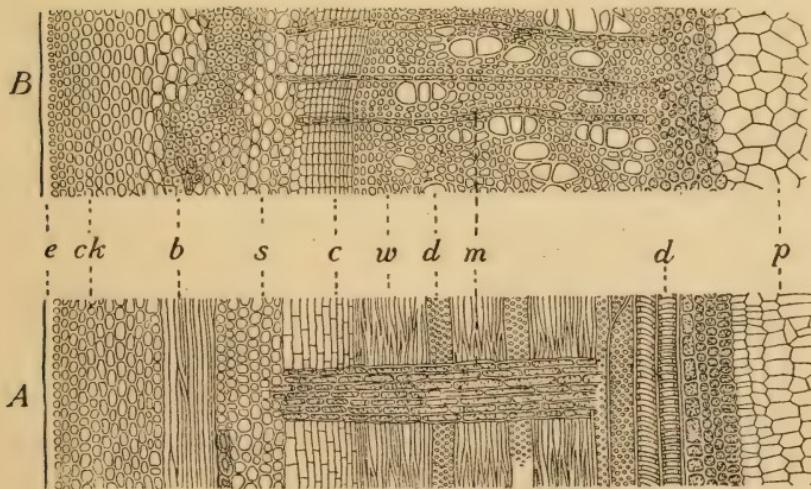
Fig. 24. Cross-section (*B*) and longi-section (*A*) of stem, greatly magnified. *P*, pith; *d, d*, water ducts; *m*, medullary rays; *w*, woody portion of stem; *c*, delicate cambium or growing cells; *s*, phloem of food-conducting cells; *b*, hard fibers; *ck*, cortex; *e*, epidermis.

bundles, but with age become so numerous that they unite to form the solid woody portion of the stem. Outside of this woody region is a layer of very thin-walled cells that are actively dividing and growing. This is the cambium layer. (Fig. 24c.)

58. **Cambium.** The cambium is the region of active growth in the stem of plants with netted veined leaves. It causes the stem to increase in diameter by adding layers of cells each season, forming the *annular rings*. (Fig. 25.) The cambium cells on the inner side become wood cells and water ducts, while the cells on the outside are gradually transformed into the food-conducting channel, or phloem,

Fig. 25.   Cross-section of an oak stem, showing the "annular" rings at *J*, which mark the close of the growing season.

just under the bark. The increasing thickening of the stem breaks the outer bark in long, vertical slits, and new bark is formed below.

59. Wounds made by pruning, gnawing of rabbits, breaking of branches, and other agencies, are often healed over by the growth of the cells of the cambium. Whenever the cambium cells form an extra growth in this way, it is called *callus*. Where large limbs are removed, it takes several years for the callus to grow over the wound. When trees are pruned, the exposed part should be heavily painted, to protect it till the callus can have time to grow over entirely. (See ¶ 186, How to Make the Cuts in Pruning,.)

60. The Phloem Portion of the Stem is important, because it is the channel through which the food substances are carried from the leaves to the roots. The water moves up through the woody portion, but the food material moves in the phlœm part of the stem. When land is cleared of large trees, the stumps will continue to form water sprouts for a long time, unless the trees are first "deadened." This is done by cutting off the bark entirely around the trunk of the tree, thus leaving a strip or girdle of the wood exposed. This does not cause the immediate death of the tree, because water can move up to the leaves through the stems, as before. However, no food can pass down to the roots, and they finally die of starvation. When the

Fig. 26.   Diagram to show the path of movement of water and reserve food substances in stemmed plants.

roots die, water is no longer absorbed, as the living root-hairs are gone. Girdling kills trees by starving the roots. (Fig. 26.)

61. Roots May Die without Girdling. When fruit trees overbear, nearly all the food formed in the leaves goes to mature the fruit, and not enough goes down to

nourish the roots, hence the trees often die early in the following spring. Sometimes a severe drought prevents the trees from forming sufficient food, or insects, fungous diseases, or storms destroy all the leaves. All the reserve food is used up in an effort to form new leaves, and the roots die of starvation. Transplanted trees that fail to make a good growth often die at the beginning of the second spring, because of the exhaustion of their reserve food.

62. Perennial Weeds and sprouts from stumps may be killed by constantly destroying all leaf growth. Even though it does not kill them completely the first season, it may weaken them to such an extent that they may be more easily killed by other means. If allowed to grow to considerable size, the roots will receive food materials sufficient to start vigorous new growth.

63. Killing Johnson Grass. Grasses and weeds that form thick rootstocks are difficult to destroy. They may be killed much more easily if they are kept grazed down, so that the leaves do not have a chance to form a store of reserve food for rootstocks. The half-starved rootstock is much more easily killed than the fully nourished one.

64. The Storage of Reserve Food. Annual plants use their food supplies as fast as formed, in developing the shoots and roots, and, particularly, in forming flowers and fruits. Some plants, like turnips, cabbage, radish, etc., store the surplus food in the stem, leaves or roots during the first season, and use it during the next season to nourish a large crop of seeds. If grown in warm climates, these plants will complete the cycle in one season. In plants that live from year to year (perennials), food is stored up in the stems and roots, to supply the

needs of the dormant season, and also to form the new crop of root-hairs, leaves and flowers in the following spring. It is the reserve food in the stems that makes the callus and new roots in cuttings of roses, privet, grape, etc. (See, also, ¶ 159.)

QUESTIONS

1. Where is the growing point of the stem? 2. What changes take place as the stem lengthens? 3. What is the difference in the arrangement of wood fibers and water vessels in the corn stalk and in plants with netted-veined leaves? 4. Where is the cambium, and what is its work? 5. How are the wounds on plants healed? 6. What is the position and use of the phloem layer? 7. Why are trees girdled? 8. How else may the roots of a tree be starved to death? 9. How may perennial weeds be killed? 10. How may Johnson grass be killed? 11. What are the uses of reserve food?

CHAPTER IX

THE PLANT AS RELATED TO THE SOIL

65. The Welfare of Plants is dependent on the nature of their surroundings. In cultivation, the effort is to make and keep the environment favorable. In open-field culture, little can be done to change the air, the temperature, or the amount of light. While the difficulty of changing the environment of the plant above ground is great, much may be done to control the environment under the ground. The fertility of the soil, the amount of water, the temperature, the supply of air, and other conditions affecting the growth of the root, may be readily changed. A knowledge, then, of the habits and needs of roots, and of how to make the soil conditions favorable, will be very practical information.

66. Uses of the Soil to Plants. (a) *Serves as a foothold*. The roots enter the soil and act as braces to keep the plant in the proper position. Plants with long stems and heavy foliage must have strong roots to enable them to withstand the action of the winds and other forces that would displace them.

(b) *Supplies the plant with important mineral foods*. The amount of food which the plant takes from the soil is small, as has already been seen, only about 5 per cent of its dry weight; yet, small as it is, these mineral foods are absolutely necessary.

(c) *The soil acts as a storehouse for water*. The plant

must have a continuous supply of water. The soil is able to store up water in the tiny spaces that separate its particles. The roots penetrate the soil and take up this water as the plant needs it. Plants can not take up solid food. All food substances must be dissolved before they can be absorbed. Hence, water is important, not only as a food, but also as a solvent for the particles of soil. The solutions pass through the thin, delicate membranes (cell-walls) of the cells (the root-hairs) by osmosis.

(d) *It retains and regulates the temperature.*

66a. Absorption of Water by Roots Illustrated. The upward movement of water absorbed by plants may be easily illustrated in various ways. A good way is to cover the end of a lamp chimney with parchment paper, as shown in Fig. 27; then fill one-

Fig. 27. To illustrate the absorption of water by roots. The plant absorbs water against the force of gravity. So will a salt solution.

fourth full with syrup. Support the chimney in a vessel of water, with the syrup at the level of the water. After a time, it will be found higher, due to the absorption of water through the membrane. It acts like a large root-hair, which absorbs water from the soil and forces it upward into the stems and leaves. The water would

not be absorbed unless the chimney contained the sugary syrup or some similar substance. It will be recalled that syrup is boiled-down sap from cane plants.

A solution of salt in the chimney would cause the water to be absorbed in the same way as the syrup, because salt, like sugar, makes the solution stronger and denser. Where two liquids are separated by a membrane, more water always goes through into the stronger solution. The bulk of the liquid in the chimney is thus increased, and is forced higher in the chimney.

67. Conditions Favorable for Root Growth. Not all plants require the same conditions for perfect development. All require some degree of moisture. Some plants do best when their roots are totally submerged in water, as the water-lily. Some land plants will grow with their roots in water, though they do best when the roots are in soil that contains plenty of air as well as water. When roots grow in a moist and very fertile soil, they are short, but have hundreds of little branches. This gives them a large absorptive surface, enabling them to readily take up the water and mineral food. When the soil is poor, or insufficiently supplied with moisture, the roots grow long and slender and have few branches. This does not mean, as some suppose, that the roots are " searching for food." When in a fertile soil, roots multiply rapidly, because they are well nourished. When in a poor soil, where the mineral food and water are insufficient, the leaves are unable to supply the roots with enough sugar, oils, proteids, etc., to make the roots multiply and grow rapidly. It has already been observed that roots will not grow vigorously when the oxygen of the air is excluded. Plenty of air is necessary for vigorous growth.

67a. To Show that Air is Necessary for Root Growth, use two jars, one filled with well-water, as shown in Fig. 28, and the other

with freshly boiled well-water. The water should be boiled to drive out all the oxygen, and a layer of cooking oil used to prevent more being absorbed from the air. Insert cuttings of willow or Wandering Jew, and keep in a warm place for a week or more. Note the time when the rootlets appear on the cuttings.

68. Moisture Promotes Root Growth on Stems. A continuous supply of moisture stimulates root growth. Portions of stems kept in contact with moist soil for some time develop roots, as is often noticed in fallen corn stalks, tomato vines, and potatoes. To make roots develop on cuttings of roses, figs, grapes, etc., we bury them in moist sand, loam, or sawdust. (See ¶ 194, Layerage.)
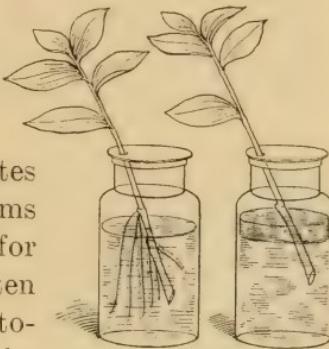

Fig. 28. Arrangement for showing the effect of the exclusion of air on plant growth. A film of cooking oil prevents the boiled water from absorbing oxygen from the air.

69. The Ideal Soil for cultivated plants is one having an abundant supply of moisture, containing plenty of soluble plant food, and so porous that air can circulate freely and come in contact with the roots. The soil may be too dense, or so compact that the air and water cannot circulate. It may be too wet,—that is, have so much water that all the air is forced out. In very wet weather, the roots are often noticed growing out of the surface of the ground.

70. Improving the Tilth of the Soil. We have already learned that the particles of the soil should be sufficiently fine for the root-hairs to grow between them. The particles may be so fine and so run together that neither the air nor the root-hairs can enter the soil. This condition is just as unfavorable for the roots as the coarse, lumpy soil. The texture, or physical con-

dition, of the soil in either case would have less water-storage space, and be less liable to set free liberal supplies of plant food. Some soils are so porous and loose that the moisture drains away, and the air circulates so freely that they dry out too rapidly.

71. Capillary Attraction is that force which causes water to rise in tubes or between particles of solid substances. The narrower the tube the higher will the liquid rise against the force of gravity. Fine-grained soils having smaller pores or spaces between their particles than coarse-grained soils, will lift water from below nearer to the surface than will coarse-grained soils. They will also hold more moisture in saturation than coarse soils, hence, are generally the better. Therefore, thorough pulverization of the soil is beneficial.

72. The Problem in Soil Management is to bring the soil to an ideal condition for the healthy growth of the roots. Some soils must have the particles made finer, and some must be made coarser by causing the finer particles to combine.

73. How to Improve the Texture. Good texture is important and dependent on the size of the soil particles. In soil treatment the object, then, is to find the best means of modifying the size of the particles until the soil is mellow and friable. There are three general ways of changing the texture of the soil:

(a) *By applying mechanical force*, as in the operations of spading, plowing, harrowing, etc. This acts directly to make the particles finer. If heavy clays or black waxy land are tilled while wet, the particles are forced closer together, and we say the soil is " puddled." This is a brickmaker's term. In making brick,

the first effort is to destroy the granular texture, which is done by wetting and working the clay. Puddled clays do not crumble when dried before baking. Neither will a soil puddled by plowing when too wet crumble into fine particles in drying. (See ¶ 105 and Fig. 40.)

(b) *By exposing the soil to the weathering influences* of the air, frost, sun, snow, etc. When a lump or clod of stiff soil is left exposed to the alternate wetting of the rain and drying of the sun, it breaks up into many smaller particles and becomes mellow. Without this weathering effect, much of our plowing would be worse than useless. The land often breaks up cloddy, but in time it becomes mellow and loose. (Fig. 29.) It requires time. In order that a soil may be in the best condition for seeding, plowing should be done long before planting time so that the weathering influences may have ample time to perfomr their work thoroughly. Some soils will weather or crumble promptly, while

Fig. 29. Waiting for time and the rains to mellow down the clods.

others, like clay, require more time. Under this head should be included some of the effects following underdrainage. (See Fig. 41.) The surplus water is thus carried off and air takes its place, and the soil particles crumble.

(c) *By applying substances which act chemically or physically upon the particles.* These are called amendments, or indirect fertilizers. Lime is a familiar example. It renders many stiff clay soils mellow, and cements or binds together the particles of a sandy soil. Fertilizers are also amendments, because they act to modify the texture of the soil as well as to supply mineral plant food. Evidence is not wanting that the good effects of a fertilizer are sometimes much greater than the amount of mineral food supplied would allow us to expect. This is probably due to the effect of the fertilizer on the texture of the soil particles. It is especially true of composts, for they serve not only to supply plant food, but also to improve the texture of the soil.

74. The Texture of the Soil affects the yield of crops to a striking degree. To improve the texture is often equivalent to an application of a fertilizer. One farmer will raise as much on twenty-five acres as another will raise on forty acres. A gardener will raise as large a plant in a small pot of soil as a farmer does in a yard of soil. It seems that the surface exposed to the action of the root-hairs in the pot of soil may be equal to the yard of imperfectly prepared soil in the field.

75. A Soil is in Good Tilth when the particles are small enough for all the root-hairs to find a surface upon which they may act. A soil in good tilth exposes a large surface to the slow action of water, air and roots. (Fig. 30.) A coarse, lumpy soil may contain an abundance of plant food, but still make poor crops. If we take a cube and cut it into halves, we increase the surface exposed by one-third; we add two sides. By dividing again, we increase the surface in the same ratio. It will be seen that a lump of soil, when sufficiently fined to be in good tilth, exposes a

large surface to the action of the root-hairs. Professor
King has figured out the result:* "Suppose we take a
marble exactly one inch in diameter. It will just slip
inside a cube one inch on a side, and will hold a film
of water 3.1416 square inches in area. But reduce the
marble to one-tenth of an inch and at least 1,000 of them
will be required to fill the
cubic inch, and their aggre-
gate surface area will be
31.416 square inches. If,
however, the diameter of
these spheres be reduced to
one-hundredth of an inch,
1,000,000 of them will be
required to fill a cubic inch
and their total surface area
will be 314.16 square inches.
Suppose, again, that the soil
particles have a diameter of
one-thousandth of an inch.
It will then require 1,000,-
000,000 of them to com-
pletely fill the cubic inch and
their aggregate surface area
must measure 3141.59 square
inches." All in one cubic
inch of soil. When all the
surfaces are moist, it is then

Fig. 30. A soil in good tilth.

perfectly plain why a fine soil will withstand more drought
and give more root-feeding surface than a coarse soil.

76. Root-Hairs Absorb Plant Food. Root-hairs absorb
the water that covers the soil particles as thin films.

*King, The Soil.

They also take in some of the substances that are dissolved in the soil moisture. Root-hairs give off carbonic acid gas and possibly other acids, which help to dissolve some substances in the soil. This may be easily demonstrated by allowing roots to grow on a polished marble slab.

77. The Amount of Root Growth is large. A plant must have a large root surface to absorb enough water to make up for the loss from a large leaf surface. A large leaf surface is, of course, beneficial, because it means so much more surface for absorbing the carbon dioxid and energy from the sun's rays. There must, however, be a balance between the activities of the root surface and the leaf surface.

78. The Distribution of Roots in the soil varies with the kind and condition of the soil, but, roughly, the

Fig. 31. When trees are dug up, the large roots are found spreading in the first few feet of soil. These roots had a spread of forty feet.

roots are said to spread through an area equal to that shaded by the branches. Only in exceptional conditions do the roots extend very deeply into the soil. Even in forest trees, the most vigorous roots are found in the first foot or two of soil. In young trees, the tap-root is often noticed to grow directly down for some distance, but, when the trees are old, the side roots will be found to be many times larger. (See Fig. 31.)

79. The Total Length of the Roots is very great. Hellriegel* noted that a vigorous barley plant in a rich porous garden soil had one hundred and twenty-eight feet of roots, while another growing in coarse-grained, compact soil had only eighty feet of roots. One-fortieth of a cubic foot sufficed for these roots. It may be readily understood that all the soil was occupied. Professor Clark, after making a number of measurements, estimated that a vigorous pumpkin vine had fifteen miles of roots and gained one thousand feet per day. Professor King, of the Wisconsin Experiment Station, estimates that if all the roots of a vigorous corn plant were put end-to-end they would measure more than one mile in length.

80. The Vertical Distribution of Roots is affected to a large extent by the depth of the plow line, particularly so on stiff clay soils. The roots extend much deeper in dry seasons than in wet ones. These facts have been found out by carefully washing the soil away from the roots, leaving them supported on poultry netting. These observations are easily explained when we consider the effect of tillage on soil conditions. Fig. 32

*Herman Hellriegel (1831-1895) devoted his life to the study of the chemistry of plant nutrition. He was the first to discover the relation of the bacteria causing the tubercles on the roots of legumes to the fixation of free nitrogen. He made many other important discoveries in agricultural science.

D

illustrates the appearance of the roots of a corn plant at silking time.

81. Shall Crops be Tilled Deep or Shallow? It is important that we know the distribution of the roots in the soils that are cultivated with plows; otherwise we might plow too deep and destroy many roots. At one of the agricultural experiment stations it was found that thirty days after planting corn, at the second
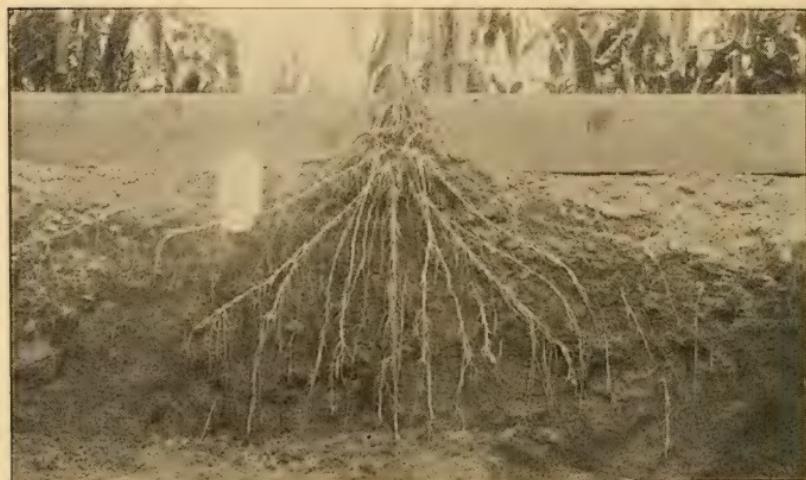

Fig. 32.   An illustration of the root-growth of a corn plant at silking time. After Hartley. United States Department of Agriculture.

cultivation, the roots from the adjacent hills (three feet apart) had already met. A few roots had reached a depth of twelve inches, but the bulk of the roots were within eight inches of the surface. Six inches from the hill, the main roots were within two or three inches of the surface. Midway between the drills they lay within four inches of the surface. Deep plowing at this time with shovel-pointed plows would certainly have injured many roots.

82. The Condition of the Soil has great influence on the distribution of the roots. Where the surface layers are moist the roots will grow freely in these layers, but if dry spells come the plants will suffer more than plants that have been growing on soils less favorably supplied with moisture. This explains why it is best, in watering lawns, to give them a heavy drenching rather than a frequent sprinkling of the surface, so that the water will soak down into the deeper layers.

83. Grass-like Plants are without tap-roots. They form a number of fine roots near the surface, and are hence known as "surface feeders." Other plants, like cotton, alfalfa, peanuts and beans, have strong tap-roots that branch out in the lower layers of soil, and are for this reason called "deep feeders." We must not conclude from this that the small grains do not have deep-feeding roots. Notwithstanding the small diameter of the root branches, some of them penetrate the soil much below the surface layers, as illustrated in Fig. 32.

QUESTIONS

1. What conditions of open-field culture are under our control? 2. What are the uses of soil to a plant? 3. What kinds of roots grow in moist, fertile soils? 4. What kind in poor soil? 5. What is an ideal soil for plants? 6. What conditions of soil particles prevent the right supply of food? 7. What are the three general ways of changing the texture of the soil? 8. When is a soil in good tilth? 9. Why is it necessary for a plant to have a large root surface? 10. What is the general rule as to the distribution of roots? 11. What is the effect of moisture on the downward distribution of roots? 12. Shall crops be tilled deep or shallow? Discuss this question. 13. Why are the grasses called surface feeders?

CHAPTER X

SOILS AND SOIL MANAGEMENT

84. From what we have learned, we recognize that the proper management of soils should be such as to:

(a) Provide the plant with an adequate supply of available soil moisture at all times.

(b) Put the soil in such tilth that the roots can find abundant supplies of the important soil nutrients.

(c) Provide for the removal of the surplus water (drainage) that would fill up the air spaces and prevent the proper development of the roots.

(d) Make the soil sufficiently loose so that the oxygen of the air and the water in the soil may circulate freely.

85. Classification of Soils. Before we can intelligently discuss the problems of soil management we should learn more about the properties of the different kinds of soils. By "soil" we mean that layer of the earth's crust which is formed from finely broken-up rocks and decayed plants and animal remains. Soils are variously classified according to origin*, method of formation, chemical composition, physical properties, or adaptations to kinds of crops. It will be advisable for us first to learn more of the properties of the substances that compose the various kinds of soils.

86. Origin of Soils. The geologist classifies soils according to their origin and conditions of formation. He tells us that all soils have been formed by the gradual breaking up of rocks. Fig. 33 shows a mountain of rock

*See chapters on Erosion in any text-book on geology or physical geography.

being slowly but surely converted into soil. The large boulders break and fall from the cliffs, and by the weathing of the rains, frosts and other agencies, they are worn away. The finer particles are washed down the hillsides into the valley below, forming the rich valley soil. Soils formed in this way by the deposit of the sediment from running water are called *sedimentary* soils. In some cases the rocks break up and are not
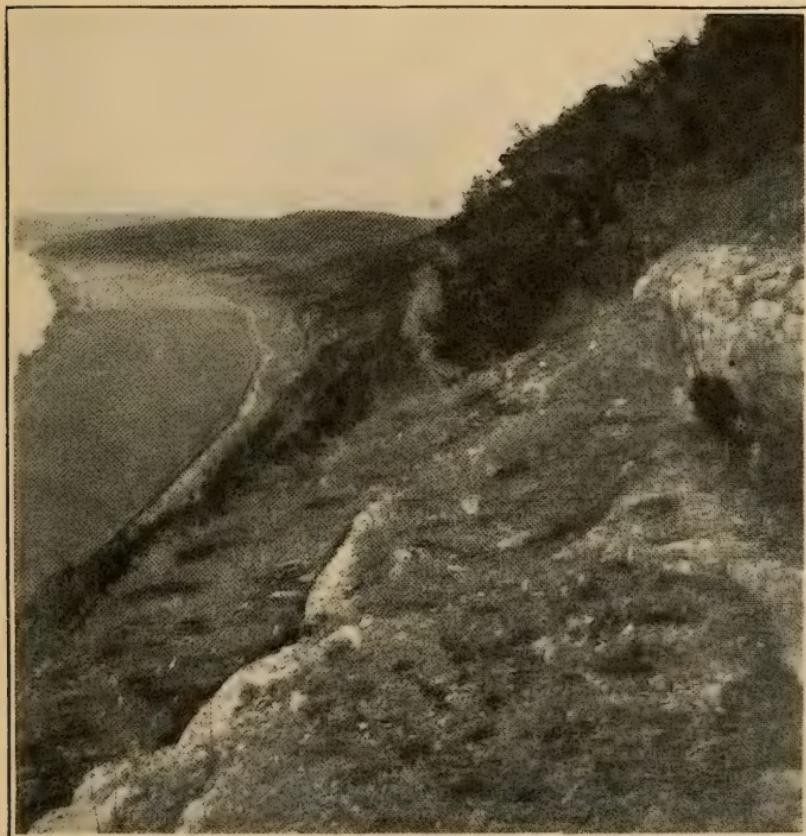
Fig. 33.   Soil formation. Rain, frost and plants all assist in changing the mountains of rock into soil. After Hill. United States Geological Survey.

removed by flowing water. Such soils are referred to as *residual* soils.

86a. Weigh a fruit jar and fill with the muddy water flowing from the field after a heavy rain. Let stand until the water is clear, and note the amount of soil in the bottom of the jar.

86b. Weigh the jar again, pour off the clear water, leaving the thick sediment. Dry and weigh the sediment, and calculate the per cent of sediment in the muddy water.

87. Other Classifications. A convenient and natural classification of soils is often made according to the color, texture and structure of the soil layers. We commonly speak of a soil as consisting of a *surface soil* and a *subsoil*.

The surface soil includes the top layer of soil—"that which is moistened by the rains, warmed by the sun, permeated by the atmosphere, in which the plant extends its roots, gathers its soil-food, and which, by the decay of the subterranean organs of vegetation, acquires a content of humus." The surface soil may be subdivided further into surface soil and sub-surface soil; the surface soil proper, or soil mulch, including the layer of top soil that is moved about by the ordinary operations of tillage, and the sub-surface soil, referring to the layer of surface soil that is just beneath the soil mulch, thus being a part of the surface soil and yet is not stirred by ordinary inter-tillage.

The subsoil is the layer just below the surface soil, and in all soils it is taken to mean the second layer, showing characteristic differences from the surface soil. Sometimes the subsoil, or a layer just beneath the top layer of the subsoil, may consist of a hard, stiff layer of clay or other compacted material, impermeable to water and air. This is spoken of as *hard-pan*. It is often absent altogether, or it may be at various depths. It

may be considered as a condition of the subsoil rather than as a different material, where it is composed of the same material as the subsoil.

88. Sand. Sand is broken-up fragments of a mineral called quartz, or flint. It often occurs mixed with considerable quantities of coarse gravel. Pure white sand is almost valueless for agricultural purposes, because it supplies no needed mineral element. However, it rarely occurs pure, but mixed with other minerals that supply plant food. Sandy soils are usually classed as "light" soils because of the light draft in plowing. They are in reality very heavy, for a cubic foot of air-dry sand will weigh over a hundred pounds, whereas an equal quantity of clay will weigh only about eighty pounds. The grains of sand are rounded, and so there are spaces between them. This allows water and gases to move easily through sandy soils. Because of their open nature, sandy soils readily take in large quantities of water. For the same reason, they allow it to drain off or evaporate quickly. Sand has the property of absorbing and retaining the heat of the sun's rays readily, and will, for this reason, warm up sooner than other soils and is, hence, preferred for growing early vegetables.

89. Clay, in an agricultural sense, includes any soil composed largely of very fine particles, which gives the land a close, compact, adhesive nature. Clay, as used by chemists and potters, refers to the disintegrated mass of certain kinds of rocks. The several kinds of clay soils vary widely in chemical composition, physical properties, and fertility. Usually, however, clay soils are very productive. Clay has the property of absorbing large quantities of water, often as much as from 50 to 75 per cent of its own weight. Even the dry clay road

dust may have as much as 10 per cent of water. When wet, clays become sticky and impervious to water and air, and, of course, root growth cannot take place when the soil is in this condition. If kneaded or puddled by working at this time, it does not crumble on drying. Clay particles have a tendency to cling together in small lumps, or floccules, especially if lime is present. This makes them more open and porous, and lightens the draft in plowing. Water evaporates slowly from clay soils.*

90. Calcareous, or Limy Soils. Many fertile soils contain large quantities of crumbled limestone (carbonate of calcium). The presence of lime in a soil may be easily detected by the effervescence (giving off of gas) when treated with acids. Strong vinegar will answer. Try it on some lumps of soil. Finely pulverized limestone has physical properties similar to clay. Lime tends to improve clay soils by making them more granular and porous. Lime also acts beneficially on sandy soils by increasing their water-holding power. The fertile black lands of Texas contain from 5 to 40 per cent of carbonate of lime. Soils low in lime often become sour or acid, (¶ 141).

90a. Effect of Lime on Clay Soils. Take about three pounds of stiff clay soil and work into a soft plastic mass by wetting and kneading. Divide into three equal parts. Round one into a ball and put on a board. Work the second up with an equal volume of air-slaked lime, and the third with half as much air-slaked lime. Put all three on a board and let dry. Describe the results. What is the effect of the lime on clay soils?

90b. Effect of Lime on Clay Particles. Clay settles slowly in water. The particles are so fine that they float in water like dust in the air. Rub up some clay in water until the water is turbid. Pour a little

*Are the clay soils of your community classed as drought-resistant soils?

of this turbid water into lime water.* What happens to the particles of clay suspended in the water?

91. Humus is the term applied to partly decayed plant and animal remains, and is well illustrated by the leaf-mold found under the trees in a dense forest. Humus gives to the soil a characteristic blackish color, and adds greatly to its fertility It improves the water-holding power in a noticeable degree, often to double the original water-storing power. It makes clay soils mellow and sandy soils compact. Humus is formed by the decay of the roots, leaves, etc., in virgin soils. The farmer is able to increase the humus in the soil by adding compost directly, and by plowing under straw and green crops, like cow-peas, etc. (See ¶ 131, Green Manuring.)

92. Examination of Soils.† An experimental study of the several kinds of soils, especially of those occurring in the school district, should be made, and, if a sufficient number of different kinds are not close at hand, others may be secured. These various kinds of soil consist of mixtures of varying amounts of sand, clay, limestone dust, and half-decayed plant remains. The fertility and water-holding power will bear some relation to the amounts of these separate substances composing the soil.

*To prepare lime water, secure a large-mouthed bottle or fruit jar. Fill half-full with water. Add lime, a little at a time, until a good handful is used. Cork securely, to keep out the air, and let stand. The lime will settle to the bottom and the clear liquid above is lime water.

†The direct examination of the samples of soil, as outlined in this chapter‘ may be conducted by any boy or girl with little or no assistance from the teacher. A word of caution may be given to the student. He should be reasonably familiar with the theory of the work he is to undertake, and what questions his results may answer. Too often he will want to say that he is "going to prove" so and so. He should be cautioned to "find out" if so and so is *true* or *not true.* This is the attitude of the true student.

93. Size of Soil Particles. In recent studies on American soils, much attention has been given to the determination of the size of the particles in good agricultural soils. Fig. 34 shows how two soils may differ in this respect. In noting the size of the soil particles, we should distinguish between the actual size of the minute particles or fragments of rocks and the soil floccules, or granules formed by the sticking together of a number of very small particles.


			Per Cent.				
Gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Fine silt.	Clay.
0.99	4.98	40.19	27.54	12.10	7.74	2.23	4.40
21	1.5	.5-.25	.25-.1	.1-.05	.05-.01	.01-.005	.005-.0001

Diameter of the grains in millimeters.

			Per Cent.				
Gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Fine silt.	Clay.
0.57	0.30	0.15	0.25	2.34	19.04	26.58	51.77
21	1.5	.5-.25	.25-.1	.1-.05	.05-.01	.01-.005	.005-.0001

Diameter of the grains in millimeters.

Fig. 34. Showing the amounts of the particles of different size in two kinds of soils from Bureau of Seeds, United States Department of Agriculture.

93a. Examination to Observe the Size of the Soil Granules. Secure a half-dozen lumps of soil from the moist layers beneath the surface, and put into a fruit jar three-fourths full of water. Screw on the top and shake vigorously for some minutes, and allow to settle. Describe the layers formed after standing one hour or more. Note the differences in size of the granules of the soil. Apply the same treatment to a handful of garden soil; to a sample of stiff clay soil.

93b. Secure a good handful of soil and moisten and work till a very thin, even paste is formed. Place in a jar, as in ¶ 92a, and shake. Allow to stand until the particles have all settled to the bot-

tom. Observe the different layers. The coarse material at the bottom is probably sand. Above this will be a layer of finer particles consisting largely of clay, the finest particles of which remain in suspension in the water, making it turbid. Small particles of vegetable matter may be found floating on the surface.

Estimate the amount of sand and clay in the samples. What effect did working the soil into a paste have on the size of the granules?

Make similar tests with a number of different kinds of soils. Make a table as shown below, and record your observation for each sample of soil.

93c. Classify the soils examined according to the following scheme. Estimate the amounts of the sand or clay.

Kind of soil	Per cent of sand present	Color of fresh soil	Productive or unproductive	Drought resistant or not	Heavy or light draft	Remarks
Sandy	80–100					
Sandy loam..	60– 80					
Loam	40– 60					
Clay loam....	20– 40					
Clay.........	0– 20					

93d. Weight of a Cubic Foot of Soil. It will not be necessary to use a full cubic foot. Small, rectangular boxes may be made and then carefully measured for their inside dimensions. The dirt may be put in these and weighed, and the results calculated to a cubic foot. Three-pound tomato cans, with the tops melted off, may be used in the same way. The samples of soils should be thoroughly dry and free from coarse lumps. Weighing should be very carefully made and recorded. A sample of every type of soils in the community should be used.

94. Temperature of Soils. Soils have the power of absorbing the heat from the sun's rays. If they absorb the heat readily they are called warm soils, and if slowly, cold soils. Dry soils get warm much more quickly than moist soils. Barefooted boys know that the dry sands and fine clay road dust becomes warm more quickly than moist soils.

The amount of water in the soil affects the temperature more than the kind of soil. Much heat is required to warm and dry out wet soils. Most of the heat is consumed in evaporating the water. The evaporation of water from the soil may be compared to the evaporation of sweat from the body, because it cools the soil, just as evaporation cools the body.
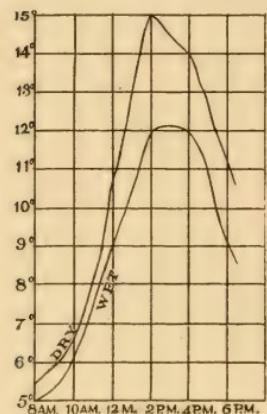
Fig. 35. Temperature curves of dry and wet soils.

The texture of the soil also affects the temperature. Coarse rocky or lumpy soils suffer from sudden changes in temperature. Loose and well-cultivated soils absorb and retain the sun's heat best; and the temperature in such soils is more uniform.

The color of the soil affects the amount of heat absorbed from the sun's rays. Dark-colored bodies absorb the heat rays more readily than light ones. This explains why dark soils are warmer than light soils.

94a. Absorption of Heat from the Sun by Dry Soils. Air-dry soils should be put into uniform vessels. Gardeners' flats are quite suitable. Insert ordinary dairy thermometers into the soil for about two inches and note the temperature in each box. Put the box in strong sunlight and make readings at 8, 10, 12, 2, 4, and 6 o'clock. Record the readings of temperature on a sheet of paper ruled as shown in Fig. 35.

94b. Rate of Cooling of Dry Soils. The same boxes used in ¶ 93a may be used. Note readings when placed in sunlight at 8, 10, and 12. Then put in shade and note the temperature at 2, 4, and 6. Which kind of soil cooled quickest? What soils retained their heat longer? Do the soils that warm quickly cool quickly? What soils would you class as "warm soils?"

94c. Absorption of Heat by Moist Soils. Use same boxes of soils

as above, but add same amount of water to each, and make readings when exposed to sunlight from 8 until 4. The cans or boxes should be weighed at the beginning, and, when through with the test in this experiment, weighed again for results in ¶ 95a, noting loss of weight in each.

94d. Loss of Heat by Moist Soils. As above in ¶ 94b. The same boxes may be used.

95. Soil Mulch.

The rain falling on the surface causes the many fine lumps of soil to crumble and run together, and leaves the surface covered by a closely compacted layer or crust. This condition of the soil is very favorable for the rapid evaporation of the capillary water. When the surface becomes dry, the water below will move rapidly to the surface and the soil will soon become dry. The thrifty farmer destroys this crust just as soon as the surface layer can be harrowed or plowed. He thus destroys the close capillary connection formed between the surface and sub-surface soil. The soil mulch should be two or three inches thick. (Fig. 36.)

95a. Rate of Loss of Water. Use three-pound tomato cans. Put equal volume of air-dry soil of different kinds in each, and add same amount of water to each. At 4 o'clock each day, note the amount of water lost from each kind of soil during four separate days, and calculate the per cent of total water lost for each day. Record the results as shown in the following table:
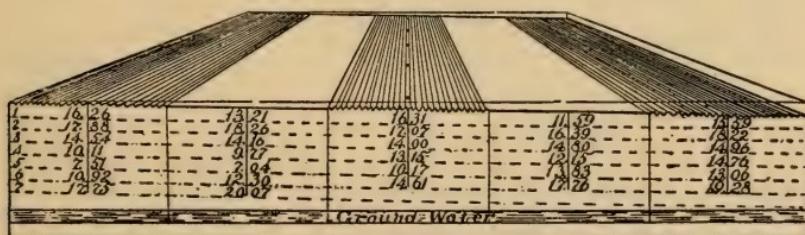

Fig. 36. How cultivation retards surface evaporation. The position of ground water after fifty-nine days, and the per cent of water in the soil at different depths. The shaded plots were cultivated. After King, University of Wisconsin.

	Weight at beginning	End of first day	End of second day	End of third day	End of fourth day	Per cent
Sandy soil						
Clay soil						
Garden soil . . .						
Coarse gravel . .						

95b. Rate of Rise of Water Through Soils of Different Texture. For this test, a number of ordinary lamp chimneys serve very well, because the results may be easily observed. These may be secured at stores. Select three samples of soil: one sand, one clay, and one a soil with much humus. Prepare two chimneys of each kind of soil, as follows: Close the tops of the chimneys with muslin. In number one, let the soil particles drop lightly into the chimney and remain very loose. In number two, pour in a little at a time and press slightly with a stick. Do not try to make too compact, lest the chimney be broken. Put all the chimneys in a vessel of water, as shown in Fig. 37, and note the rise of the moisture every recess hour.

Fig. 37. To test the rise of water through soils of different texture.

What effect does compacting the soils have on the quickness with which they absorb water in sand? In clay? In humus? Would the water percolate down through these soils in the same way; and rate? Try it.

95c. Effect of Mulches on Evaporation of Water from Soils. Secure seven or eight three-pound tomato cans from which the tops have been melted carefully off to leave smooth rims. Fill

three of the cans full to the upper edge with clean, dry sand or other soil. Fill the remaining ones within one inch of the top. Weigh the cans separately when dry, and add the same amount of water to each one and note the weight. Prepare the mulches as indicated below, and weigh again. Set in a convenient place
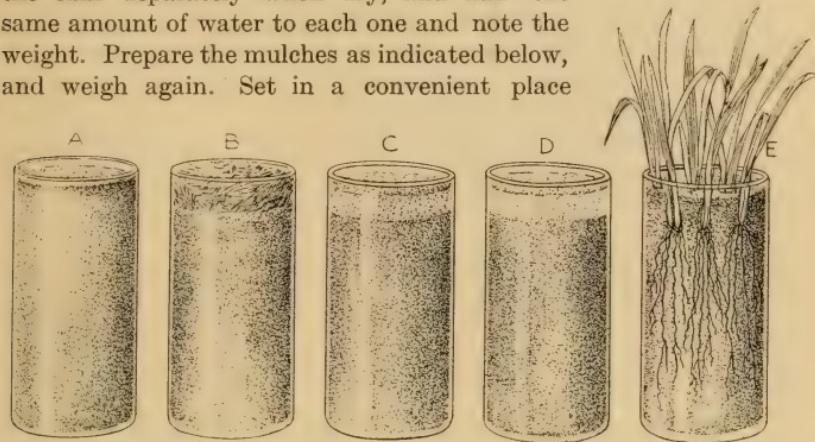

Fig. 38. Consuming soil moisture. Loss in seven days: *A*, packed surface, 8½ oz. water; *B*, fine chopped straw, 2 oz. water; *C*, covered with loose sand, 1 oz. water; *D*, dust mulch, 3 oz. water; *E*, young oat plants, 10 oz. water.

where they will all be exposed to the same conditions. Weigh daily for one week or ten days, and record the loss of weight for each can on the following table. The difference in loss will approximate the power of these separate mulches to retard evaporation from the surface. Give all the cans the same exposure to light and wind.

Effect of Mulches on Evaporation

No. of can	First day		Second day		Third day	
	Weight	Loss of weight	Weight	Loss of weight	Weight	Loss of weight
1						
2						
3						
4						
5						
6						
7						

1. Not mulched. (Check or control.)
2. Surface cultivated one inch deep (soil mulch).
3. Surface cultivated two inches deep (soil mulch).
4. Mulch with one inch of coarse gravel.
5. Mulch with one inch of sawdust.
6. Mulch with one inch of fine sand.
7. Mulch with one inch of fine cut straw.

Which mulch is most effective?

Which mulch is most practical under field conditions?

What other conditions affect evaporation from the soil?

96. Soil Moisture Retained by Cultivation. Professor King has investigated the efficiency of surface cultivation in retaining water in the soil. A piece of fallow ground was divided into plots twelve feet wide, as shown in diagram in Fig. 36. Three were cultivated and two left fallow. The figures in the table show the per cent of water in the soil of each plot, at different depths, at the end of fifty-nine days. The average loss of water from the cultivated plots was 709.4 tons per acre, while in the non-cultivated plots the loss was 862.3 tons per acre. This makes the mean daily loss of water from the ground not cultivated 3.12 tons per acre greater than was that from the cultivated soil.

97. "Dry-land Farming." In some sections of the country where the rainfall is so light that the trees and other large plants requiring large amounts of water will not grow, the soil mulch has been found to be an excellent conserver of soil moisture. A crop is grown only every other year. The fields are divided into two parts. One is planted in grain, and the other will be harrowed after each rain, or oftener, to form a mulch. In this way, the water is stored up one season for the next season's crop, and from twenty-five to fifty bushels of grain to the acre are harvested every other year. If

a crop were grown every year on all the land, the yield would not average ten bushels per acre.

98. How Plants Dry the Soil. Do plants take moisture from the soil faster than ordinary evaporation? To get an answer to this question, fill four tomato cans with a good garden loam. In one plant nothing; in another, forty or fifty grains of oats; in another, five or six grains of corn. Put an elder stem or hollow cane on the side of each so that the plants can be watered from the bottom. If we put water on the surface, a crust will form that will cause the water to evaporate much faster. (Do any of our experiments justify this statement?) Pour just enough water down the tube to make the soil reasonably moist, but not too wet. Set in a warm place, and, when the seedlings are half an inch high, weigh the cans and determine the loss of moisture in the usual way. Keep the cans in a place where the plants can get a good light, but not where the sun would heat the earth too much. Sum up your results at the end of the first week, and answer the questions given above. Likewise, at the end of the second week.

99. Absorptive Power of Soils. Soils have the power of absorbing many substances, particularly some that are valuable plant foods. The soil is a great purifier of water. Prepare two lamp chimneys as described in ¶ 95b, and fill with good field or garden soil. Into one pour several ounces of water made deep blue with laundry blueing. Note the color of the water when it comes through the cloth below. Into the second chimney pour foul water made by leaching compost. Use as before.

Wood ashes contain the salts left from the plant when the air-derived substances have been driven off by burning. It represents the valuable salts absorbed

E

from the soil. Take some home-made lye and taste a drop on the end of a broom straw. Allow to filter through the soil as above and try the taste of the drippings. Has the soil absorbed any of the salts?

QUESTIONS

1. What are the ends to be worked for in soil management? 2. What is meant by "soil?" How does a geologist classify soils? 4. What is the farmer's classification of the layers of soils? 5. Name the four chief components of soils. 6. What are the advantages and disadvantages of a sandy soil? 7. Of a clay soil? 8. Of a limy soil? 9. Of humus in soils? 10. What is the importance of the size of soil particles? 11. Which are more important, soil particles, or granules? 12. What does the farmer mean by heavy and light soils? 13. What kind of soil warms up most quickly? 14. Why does the farmer harrow or plow up the crust formed by rains? 15. What is meant by dry-land farming? What is its advantage?

CHAPTER XI

WATER IN THE SOIL

100. How the Water Exists in the Soil. From our experiments, we have noticed that the water in the soil may be classed as:

(a) *Free, or gravitation water*, the water which flows under the influence of gravity and percolates downward. When the water collects below, we call it bottom, or ground, water, and the upper layer is called the *water table*. (See Figs. 36 and 41.)

(b) *Capillary water* is held in the capillary spaces or pores of the soil and is not influenced by gravity, but moves upward, or in any direction where the soil is becoming drier. It is held in the soil by the same force which causes the whole of a rag to become wet when one end is placed in water, or which causes oil to rise in the wick of a lamp. The amount of capillary water, that is, the water which the soil may retain against the influence of gravity, depends on the size and form of the soil particles, and several other conditions. Where there is only capillary water in the soil, there is, of course, some

Fig. 39. Diagram to illustrate how the soil particles are covered by capillary water.

(67)

air space, because the capillary films will not be thick enough to fill the spaces between the grains, especially if the soil is coarse grained. This is the condition most favorable to the growth of roots, because both water and air are present. (Fig. 39.)

(c) *Hygroscopic water* does not differ essentially from capillary water, except that it is held more firmly to the grains. Air-dry soil may still contain from one to ten per cent of hygroscopic water,—that is, water which may be driven off only by heating to the temperature of boiling. Clay soils, in particular, often contain large amounts of hygroscopic moisture.

100a. Rate of Percolation of Water Through Soils. Prepare lamp chimneys as in ¶ 95b, filling them two-thirds full, using different kinds of soil. Quickly fill all the chimneys full to the top with water, and then notice the time required for water to begin dripping at the lower end. It will be well to place small-mouthed bottles under each chimney to collect the drippings. In this way the amount of water percolating through the different soils may be estimated. Which would be preferable in field conditions, for the water to percolate rapidly or slowly? Discuss this question.

Soil	Time required for first flow from bottom of chimney	Amount of water passed through chimney at end of		
		First day	Second day	Third day
1				
2				
3				

101. The Amount of Capillary Water which a soil may retain varies with the soil. This is a measure of the power of a soil to store up water. The following table, taken from Schubler*, who first investigated this property

*See **Johnson,** How Crops Feed.

of soils, gives a good idea of the water-storing power of
the different soils:

	Maximum capillary water	Water lost in four hours
	Per cent	Per cent
Pure sand	25	88.4
Lime sand..............	29	75.9
Clay soil (60% clay).......	40	52.0
Loam	51	47.5
Heavy clay (80% clay) ...	61	34.9
Pure gray clay	70	31.9
Fine carbonate of lime	85	28.0
Garden mold	89	24.3
Humus	181	25.5

The second column shows the per cent of water
that evaporated in four hours, when spread over a given
surface. It is seen that soils having capacity for large
amounts of capillary water part with it very slowly.

**102. What amount of water is most favorable to
the growth of plants?** This has been experimentally
studied by Hellriegel, who found that oats, wheat,
and rye growing in sand able to hold twenty-five per
cent capillary water made maximum yield with fifteen
to twenty per cent water. He observed that the plants
would grow with no less vigor when the soil contained
even only 2.5 per cent water. Below this the plants
would wilt. It is not generally true that the most
favorable amount of moisture for the growth of a plant
is the full capillary power of the soil, as might be inferred
from the above results. The results of some investi-
gations of the United States Department of Agriculture
show that plants might suffer for lack of water (drought
limit) when the soil contained 15 per cent moisture,
while in other soils the plants were well supplied

when the soil contained only 4 per cent moisture. In some soils 20 per cent moisture caused injury, while in others only 10 per cent moisture acted injuriously on the plants. These figures indicate approximate amounts only. While the range from the "dry" to "wet" seems narrow, it should be remembered that 1 per cent difference in water in the first foot of soil would amount to a rainfall of only about 0.65 inch for clay soil and 0.50 for sand, allowing 80 pounds per cubic foot for clay soil and 110 pounds for sand. Water weighs 62.31 pounds per cubic foot. One inch of rainfall completely absorbed would increase the percentage of moisture about six per cent.

103. In Irrigation it is important to know how much water to apply. Injury may be done by applying too much water, besides causing undue expense in handling the water.

103a. How much water should be applied to a sandy loam soil weighing 90 pounds per cubic foot to raise the moisture from 3% to 20%?

104. What Becomes of the Rain? The average annual rainfall at Guthrie, Oklahoma, is about thirty-two inches; that is, in a year's time, the rain, snow, and sleet would be sufficient to cover the surface thirty-two inches deep in water. In some parts of the South the rainfall is fifty inches, and in other sections only about fifteen. What becomes of this large amount of water? Some of it runs off into the creeks before it can be absorbed by the soil. This is called the "surface run-off," or simply surface water. This water is lost for the use of the plants. When the surface layers are hard and compact, the water can not be absorbed quickly, and may even flow off while the roots in the deeper layers are

suffering from a lack of moisture. If the fields were kept well plowed, more of this water would soak into the soil and could later be used by the plants when dry times come. If more water soaks into the layer of tilled soil than it can retain by its capillary properties, it is absorbed by the sub-soil and may finally percolate down to the layer of rock or clay and flow off to form springs. It is much better for the farmer if the surface soil and the sub-soil are well supplied with water. The rains are usually not abundant in the season when they would be most beneficial in increasing the yield of the crops. This fact suggests all the more strongly the importance of studying the ways that may be used to:

1. Increase the ready absorption of the rainfall;

2. Increase the water-storage power of the soil occupied by the roots (¶ 100);

3. The efficiency of mulches in conserving the moisture.

105. Increasing the Water-Storage Power of the soil may be accomplished in two ways: (a) *By deep breaking*. This increases the pore space in the soil by making the granules of soil smaller. They, therefore, have more capillary space (¶ 95). Breaking should be done in the fall so that the winter rains may be absorbed.

Fig. 40. Diagram to illustrate the effect of ideal plowing. The compactness of the soil is indicated by the density of the shading. Before plowing, there is a compact surface crust (*s*), below which the soil grows less compact as we go deeper; after plowing, this compact mass is broken up into a loose, friable mass of soil-crumbs, or floccules, with a consequent increase in the bulk of the furrow-slice (*fs*); compacted plow sole at *pl*. Modified after Hilgard.
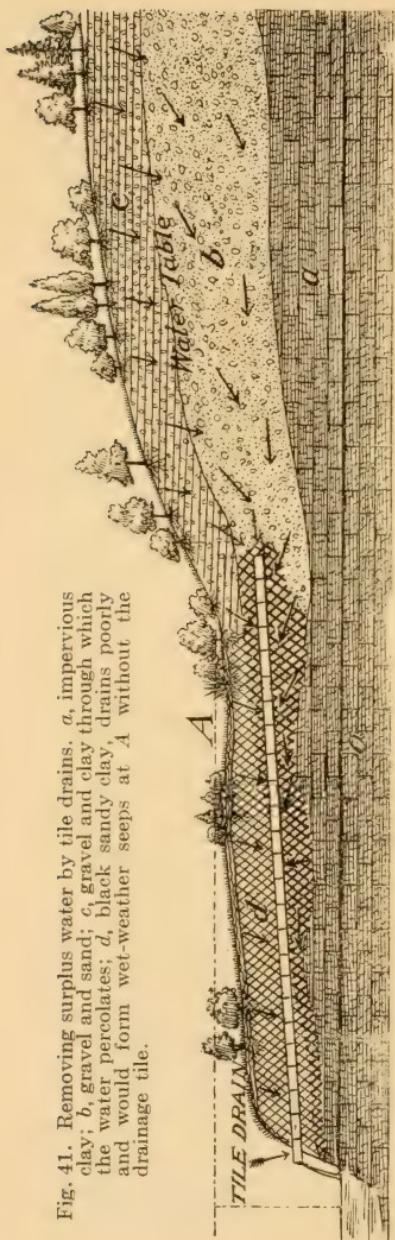
Fig. 41. Removing surplus water by tile drains. *a*, impervious clay; *b*, gravel and sand; *c*, gravel and clay through which the water percolates; *d*, black sandy clay, drains poorly and would form wet-weather seeps at *A* without the drainage tile.

(b) *By adding substances to the soil that increase its water-holding power*, such as compost and green manures (¶ 101). Increasing the water-storage power of the soil tends to lessen washing. The water "runs" after every little shower in the hard roadway, but in the well-plowed field the rain is soon absorbed and passes to the deeper layers of soil.

106. Amount of Water Required to Mature a Crop. For every pound of dry matter made by growing corn, cotton, oats, etc., it has been estimated from many experiments that from two hundred to four hundred pounds of water are required. This includes the entire plant above ground, regardless of that which is harvested. Accepting these figures as nearly correct, let us estimate how much of the rainfall is consumed in maturing a good crop of corn, cotton, oats, etc. In a field of corn making fifty bushels per acre the figures would be roughly as follows:

50 bushels corn (72 pounds to bushel)...3,600 pounds
Stalks and leaves 3,600   "

Plant substance 7,200   "
Approximate quantity of water required
   for each pound of plant substance...   300   "

Water used by crop 2,160,000   "

A cubic foot of water weighs 62.3 pounds. A rain-fall of one inch would be 5.19 pounds per square foot of soil, or $43,560 \times 5.19 = 226,175.40$ pounds on an acre. Dividing 2,160,000 by 226,175.40, we find that less than ten inches of rainfall would be used by the plants in making fifty bushels of corn per acre. This does not include the water that would evaporate from the soil or be lost by the surface run-off.

106a. At Stillwater, Oklahoma, the average annual rainfall is about 33 inches. What per cent of this would be required to make 50 bushels per acre? What is the average rainfall in your county? See page 74.

107. Soil Drainage. There are many places in low bottom lands on which water accumulates to an injurious extent, either from seepage from the hills or from the lack of an outlet for the surplus water in very wet spells. Again, there are low "sweeps," "swags," "runs," "sloughs," and the like, in which water stagnates to the detriment of the soil and the crops. Such places may often be greatly improved by making surface ditches or by placing drainage tiles (Fig. 41) to carry off the surplus water. In making open ditches it is better, if circumstances allow, to make them broad with sides sloping up about one foot in three or four. This will permit of the cultivation of the drainage-way, and leave no banks to harbor weeds or interfere with the driving

of the plows in any direction. Sometimes underground drainage ways are provided. These are often made by digging narrow ditches to the proper depth and filling partly with coarse stones, logs, etc., before refilling. The surplus water finds an outlet through the spaces between the stones. Regular drainage tiles are now most often used in place of loose stone. They may be secured in any size to suit the local conditions. Many fields have been greatly improved by placing rows of tile drains every thirty feet or so. The prompt drainage of some soils is just as important as the conservation of water in others. An excess of water delays the warming of the soil in spring, and prevents the growth of the roots.

QUESTIONS

1. In what three forms does water exist in the soil? 2. Explain capillary water. Hygroscopic water. 3. Between what per cents of water content do plants grow most vigorously? 4. Can an irrigated field have too much water? 5. What becomes of the rains? 6. What can the farmer do to make use of a greater amount of the average rainfall? 7. About how much water is used for every pound of dry matter made by growing cotton, or corn? 8. Why is soil drainage important? 9. How should open drains be made? 10. What is a tile drain?

ANNUAL PRECIPITATION IN OKLAHOMA

STATIONS	COUNTY	1889	1890	1891	1892	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902	Average
Ames	Woods								30.97				23.78	18.23		29.00
Arapaho	Custer						21.47	31.03	25.19	26.69	32.24	28.92	29.36	12.35		27.07
Beaver	Beaver								11.84			21.03	16.69			15.48
Blackburn	Pawnee				45.84	27.75					35.64		47.85	28.60		38.22
Burnett	Pottawatomie						25.10	36.17	26.08	33.47	43.20	34.36	29.91	19.12	42.76	33.07
Chandler	Lincoln														46.41	
Clifton	Lincoln														36.19	
Cloud Chief	Washita	31.91	28.79				22.29	38.19	19.43	32.69	38.75			22.96	39.11	30.07
Ft. Reno	Canadian	29.29	31.08	26.77	33.51	29.40	18.28	22.78	19.13	25.56			37.12	19.18	40.14	28.33
Ft. Sill	Comanche			32.76	34.32	24.19	24.08	29.17	17.12	26.29	37.35	46.51	36.47	16.07	46.79	30.89
Guthrie	Logan						22.99	30.69	31.71		37.73	32.62	29.83	19.33	42.19	31.92
Hennessey	Kingfisher										38.54	35.19	29.89	19.32	31.58	30.74
Jefferson	Grant						17.69	21.56	26.01	27.90		30.61	27.81		27.82	27.01
Jenkins	Woods										28.26		28.42	18.92	30.84	27.41
Kingfisher	Kingfisher										39.73	34.45	30.56	26.13	42.55	34.68
Mangum	Greer					11.39	19.52	32.89	22.85	22.49	30.91					23.34
Newkirk	Kay												26.06	28.79	43.96	32.93
Norman	Cleveland			37.43				34.78	23.80	31.24			37.11	19.19		29.22
Oklahoma City	Oklahoma				42.29	24.28	26.72	32.50	21.90	28.47	35.88	43.66	31.45	15.74	41.14	31.79
Pawhuska	Osage Nation							—			54.24	57.96		24.54	47.24	46.00
Perry	Noble											34.43		24.04	41.11	33.20
Sac and Fox Agency	Lincoln								25.95				35.17	20.80		27.31
Stillwater	Payne									31.38	42.62	32.87		19.98	40.21	32.84
Taloga	Dewey												29.98	17.33	28.37	22.85
Waukomis	Garfield									29.20	29.20	31.29	28.81	21.18	33.94	28.88

This table shows the amount of precipitation (rain, snow, etc.) by counties in Oklahoma for the years given, and the average by counties. The average rainfall for the state is about thirty inches.

RELATION OF THE PLANT TO THE CHEMICAL COMPOSITION OF THE SOIL

"The soil is not only a sponge, from which the plant may obtain water, but it is also a storehouse of plant food and a laboratory in which the plant food is prepared and dissolved for the plant."—Osterhout, Experiments with Plants.

108. In the preceding chapter, the relation of the plant to the water contained in the soil, and the means by which the water supply may be increased, have been discussed. These tillage operations not only cause the water to be retained for the use of the plants, but dissolve the mineral food elements in the soil. While the amount, the kind, and the condition of these soil foods affect very greatly the fertility or agricultural value of a soil, we should remember that, without resort to means for improving the mechanical condition, many soils, naturally rich in plant food, would yield poor crops. We should study closely the relation of the chemical composition of the soil to the fruitfulness of the crops.

109. The Essential Elements. By growing plants with their roots in a medium of known composition, plant physiologists have determined which elements of the soil are really necessary for the healthy, normal growth of the plant. By the same means they have been able to determine the effect of other substances. For these tests, the plants are usually grown in vessels thoroughly

cleaned and partly filled with distilled water (water cultures), or with pure sand (sand cultures), to which is added solutions containing the different substances supposed to be necessary for plants. These solutions are made similar in every respect to the solutions as they occur naturally in the soil. Plants have been grown to maturity in these artificial solutions side by side with ones just like them planted in the ground, and with equally satisfactory results. Where it was desired to determine if, say, potassium was really necessary, a solution was prepared having all the ingredients found in the soil waters except potassium, and in this the plants would be grown. Fig. 42 shows the results of growing buckwheat in a complete or normal nutrient solution and also when certain important elements are withheld. It should be remembered that some potash, calcium, etc., was in the seed so that not all the mineral nutrients are kept from the plantlet. Sodium, while quite similar to potassium can not replace potassium as a nutrient.
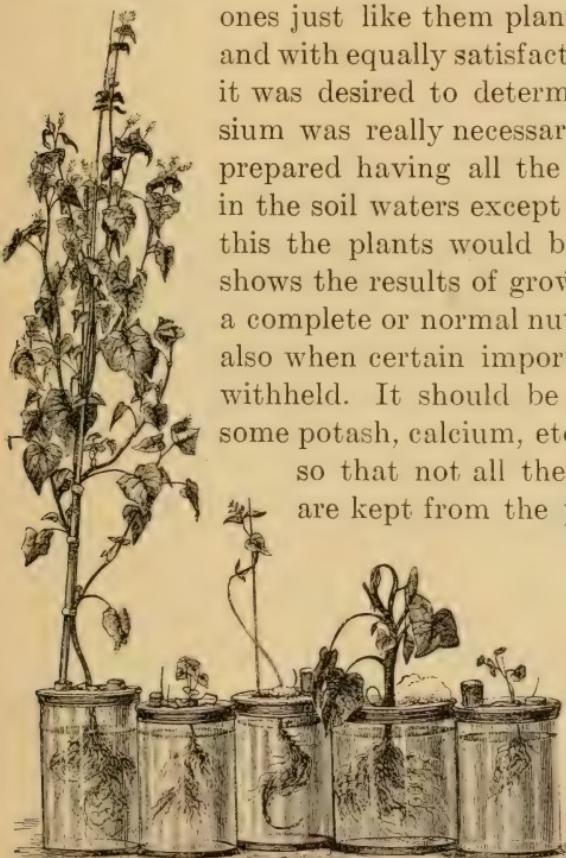
Fig. 42. Buckwheat grown in artificial solutions of mineral nutrients *A*, complete solution; *B*, potassium withheld; *C*, nitrogen withheld; *D*, calcium (lime) withheld; *E*, without potassium, but sodium added. Drawn from photograph by Nobbe.

110. Effect of Fertilizers. Another way of testing the effect of a substance is to grow the plants in some

available soil and *add* the substances to the soil. This is called fertilizing the soil. Fig. 43 illustrates the effect of applying different fertilizing substances to a sandy soil taken from a field in Eastern Texas. Fig. 44 shows the effect of adding nitrogen, potassium and phosphorus to pot-cultures of alfalfa made at the Oklahoma Agricultural and Mechanical College.
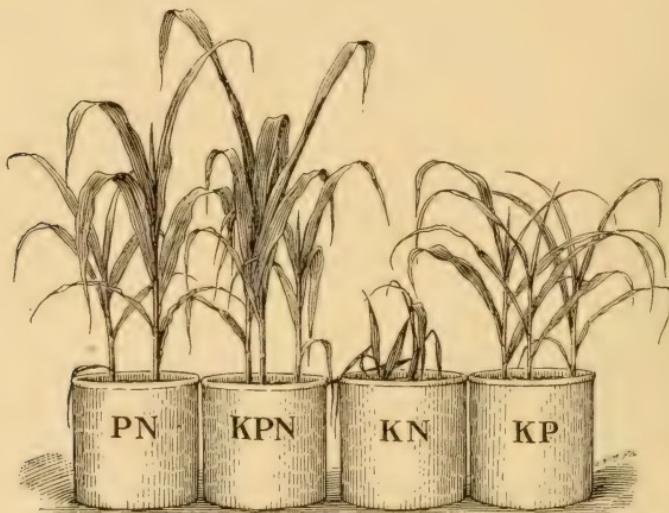
Fig. 43. Orangeburg fine sandy loam. An application of phosphoric acid is denoted by P; potash by K; nitrogen by N.

111. The Quantity of Fertilizing Substances added to the soil is but a small fraction of the increased weight of the crop which it produces. Minerals are absorbed by the plants in exceedingly small amounts, for they form only about one part in two hundred of the fresh, living plant, and rarely more than five per cent of the dry substance. They are necessary as food substance; they become a part of the living plant substance. Exceedingly small amounts suffice in the case of iron, sulphur, chlo-

rine, calcium, and magnesium. The substances named occur in nearly all soils in quantities sufficient to supply the plants abundantly. Other substances, as potassium, phosphorus and nitrogen, are more important, and must be supplied when necessary. (See table of fertilizing substances in feed-stuffs in Appendix).

112. The Form in Which Plants Take Up Their Mineral Food. These "elements" occur in the soil as compounds with other substances. The soil is composed mostly of

Fig. 44. Pot cultures of alfalfa showing effect of adding different fertilizers. D9, nothing; D10, nitrogen; D11, potassium, and D12,-phosphorus. Photograph from Oklahoma Agricultural and Mechanical College.

insoluble compounds, which the plants cannot use. The particles are very slowly changed into soluble compounds, and in this form are absorbed by the plants. The amount or per cent of soluble matter in the soil water at any one time is exceedingly small, as shown by the analysis of natural waters. In fact, if the amount should exceed ten parts in a thousand the effect would be unfavorable on the growth of the plant. The total amount of, say, potash in the soil may be several per cent of the total soil weight, yet the amount in solution at any time may rarely exceed fifty parts per million of water. It is well

that this is so, for, otherwise, the valuable soil constituents would be washed off to the sea by the percolating water. It is the great solubility of some substances, like nitrates, that explains their scarcity in the soil.

MINERAL MATTER DISSOLVED IN 100,000 PARTS OF DRAINAGE WATER.

	Field No. 1	Field No. 2	Field No. 3
Potash.................	trace	trace	0.07
Phosphoric acid..........	trace	0.17	trace
Nitrogen compounds......	10.27	21.17	2.79
Soda...................	1.43	3.10	1.24
Lime	6.93	10.24	2.23
Soluble organic matter....	10.00	10.57	8.00
Other substances.........	16.25	12.04	6.89
Total.............	44.88	57.29	21.22

113. Chemical Change in the Soil. The soil is the seat of constant changes, and these changes have great influence on the productiveness of the soil. When the soil is plowed, the particles are exposed more to the action of the air, water, frost, etc. When humus is put into the soil, acids are formed as the humus decomposes, and these tend to dissolve the substances in the soil.

114. Soil-Bacteria. Humus also encourages the growth of soil bacteria, because they live on plant and animal remains. These bacteria decompose the humus, and, in doing so, set free carbonic acid, which aids in dissolving the particles of soil. Thus it is that the bacteria of decay act beneficially on the soil. Other species of bacteria cause the formation of nitrates from insoluble nitrogen compounds. No soil will long remain fertile unless the supply of organic matter is kept up.

115. Effect of Wheat and Barley Grown Continuously on the Same Land. Some results from the famous experiments of Laws and Gilbert at the Rothamsted estate* are very instructive in showing the effect of growing crops continuously on the same soil. Wheat and barley, as well as other crops, have been grown on the same land through a series of years without manuring. Adjoining these non-fertilized crops were others treated annually with barnyard manure. Tests were also made of the effect of various other fertilizers. The results are given in averages for periods of eight years. They show that the annual application of manure increased the average annual yield twenty bushels per acre for wheat and thirty-two and one-eighth bushels for barley.

EFFECT OF CONTINUOUS CROPPING WITH AND
WITHOUT MANURING.

	Wheat. Bus. per acre		Barley. Bus. per acre	
	Un-manured	Manured	Un-manured	Manured
8 years, 1844–51	$17\frac{3}{5}$	28	. . .	. . .
8 years, 1852–59	$16\frac{1}{3}$	$34\frac{3}{8}$	$24\frac{1}{4}$	$44\frac{1}{4}$
8 years, 1860–67	$13\frac{1}{2}$	$35\frac{3}{4}$	18	$52\frac{3}{8}$
8 years, 1868–75	$12\frac{1}{4}$	$35\frac{3}{8}$	$14\frac{1}{2}$	$49\frac{1}{2}$
8 years, 1876–83	$10\frac{1}{2}$	$28\frac{5}{8}$	$14\frac{5}{8}$	$52\frac{1}{4}$
8 years, 1884–91	$12\frac{3}{4}$	$39\frac{1}{4}$	$11\frac{3}{4}$	$44\frac{3}{8}$
8 years, 1892–93	$9\frac{1}{2}$	$33\frac{3}{4}$	$10\frac{3}{4}$	$49\frac{1}{2}$
Average 50 years	$13\frac{1}{2}$	$33\frac{1}{2}$	$16\frac{1}{2}$	$48\frac{3}{8}$

*Rothamsted Estate, Hartfordshire, England, the home of noteworthy investigations in agriculture under the Laws Agricultural Trust, was founded in 1843 by Sir J. B. Laws. These investigations, directed by Sir Joseph Gilbert and the distinguished founder for more than half a century, have had great influence in shaping the agricultural practices of the world.

F

IMPROVING THE CHEMICAL NATURE OF THE SOIL

116. What Plants Remove from the Soil. The amount of mineral food substances removed from the soil by a bountiful harvest is considerable. The object of fertilizing is not only to return to the soil the elements that help the growth of the crops, but also to improve the tilth. In applying fertilizers, we should remember that our effort is to bring about a twofold result: (*a*) to supply mineral food, and (*b*) to improve the texture of the soil. While, ordinarily, we add substances supplying soluble salts containing nitrogen, potassium, and phosphorus, it should be remembered that equally beneficial results are sometimes secured by applying dressings of substances that do not contain any considerable quantities of these elements, as lime, plaster of Paris, or gypsum. The benefits derived from these substances are due to the effect they have on the physical properties of the soil. The lime may also cause the decomposition of insoluble particles containing potassium or phosphorus. (Fig. 45.)

116a. Corn contains about 1.58 per cent of nitrogen; 0.37 per cent of potassium; and 0.57 per cent of phosphorus. How much of each does a crop of 50 bushels per acre remove from the soil?

117. Not All Soils Need the Same Fertilizer. Experiments have shown that the chemical analysis of a soil does not give a farmer a satisfactory guide as to what fertilizer to apply to his land. The analysis might show a high per cent of potash, and yet it might be in such
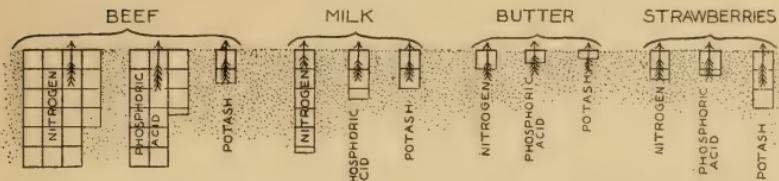
A. Showing the amounts of nitrogen, phosphoric acid, and potash removed from the soil when 1,000 pounds each of beef, milk, butter, and strawberries are sold.
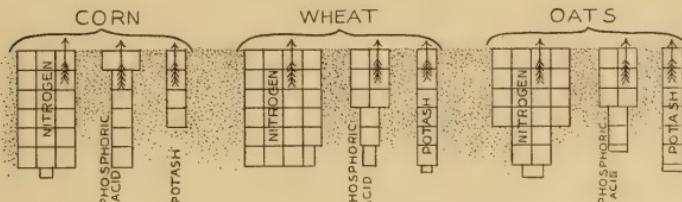
B. Showing the amounts of the three most important plant foods removed from the soil by growing 1,000 pounds each of corn, wheat, and oats.

C. Showing the amounts of the three principal plant-foods removed from and returned to the soil by 1,000 pounds each of cotton lint, cotton seed, and alfalfa.
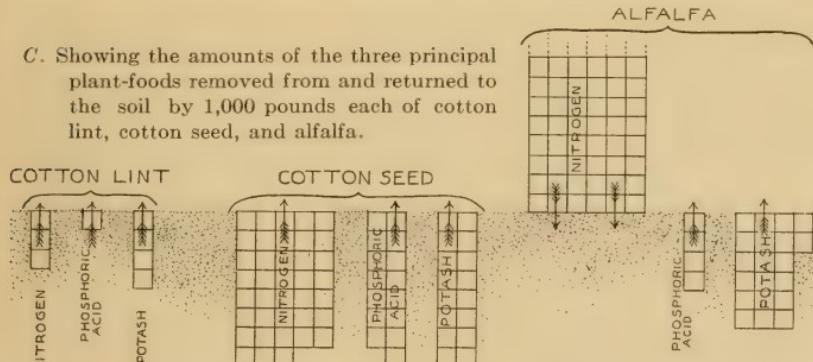
Fig. 45. Tables showing the amount of mineral food substances removed and returned to the soil by various crops.

insoluble combinations that the plants could not absorb it. This would not be the general rule, however. Usually, where the soil analysis shows a high per cent of an essential element, fertilizing with substances containing this element rarely give returns above the cost of the fertilizer. The only safe rule by which to learn

the needs of a particular field is to make trials, using a variety of fertilizers, and thus observe what fertilizer gives most satisfactory results. These tests must be made for each soil formation. (See ¶ 133.)

118. Kinds of Fertilizers. Fertilizers are variously classed, according to the valuable element they supply, as nitrogenous fertilizers, phosphate fertilizers, complete or balanced fertilizers; or according to source, as home fertilizers, commercial fertilizers. In most instances the substances applied to the land contain more than one valuable element, as, for instance, composts, which, being made out of plant remains, contain all the mineral elements found in plants.

119. Potassium Fertilizers. The most important source of potash fertilizers is the famous Stassfurt mines of Germany. The most common forms known to the markets are the sulphate, muriate and kainit—the latter a mixture of several salts. All are readily soluble and therefore are classed as "quick fertilizers." Wood-ashes form an important source of potash, though their value depends much on the source, and the way in which they have been cared for. If leached out by the rains, their value as a fertilizer is much lessened. Lime and gypsum often have the effect of potash fertilizers, causing the decomposition of insoluble potash compounds in the soil, and thus indirectly acting as potash fertilizers. The "home-made lye" obtained from ashes is largely potash.

120. Phosphorus Fertilizers. Phosphorus is an important fertilizer. Three-fourths of the phosphorus absorbed from the soil is deposited in the grain of the crop, and is, therefore, ordinarily sold from the farm, while only one-fourth remains in the straw. Phos-
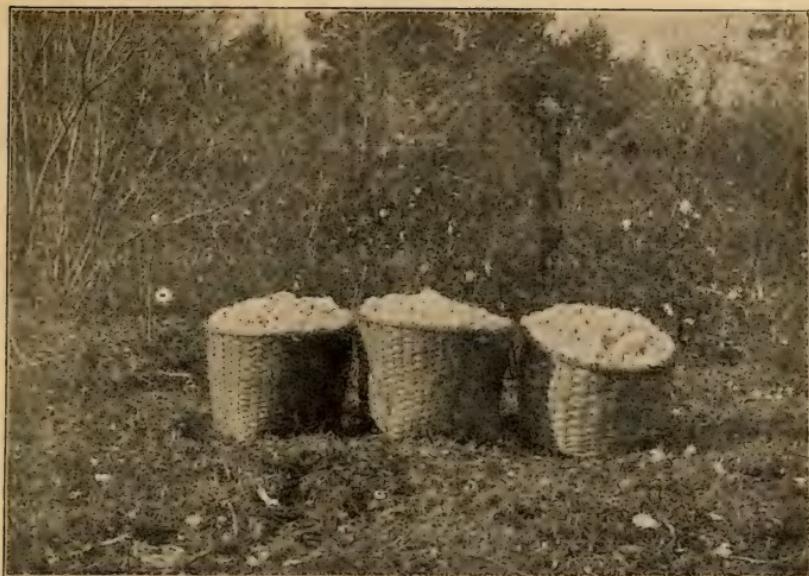
Yield from one-tenth acre. No fertilizer.

Yield from one-tenth acre, with fertilizer containing phosphoric acid, nitrogen and potash.

Fig. 46. Some soils are made more productive by fertilizers.

phorus compounds are widely distributed, though, usually, in insoluble compounds. Phosphorus is found in the soils combined with lime, magnesia, iron and alumina. For fertilizing purposes it is obtained from bones, oyster shells and rocks formed by the deposit of similar remains. In bones it exists as the insoluble lime phosphate. To overcome this, the rock or bone phosphates are treated with sulphuric acid which converts the insoluble into soluble compounds. When applied to the soil it soon returns to the insoluble salt, dicalcium phosphate. This latter is soluble in the presence of carbonic acid formed by the roots and decaying humus, and is hence readily available. (See ¶ 76.) Phosphorus fertilizers do not give beneficial results when applied to soils containing an excess of lime, like most of the "black waxy" soils.

Bone-black, formed by heating raw bones in the presence of air, is used in large quantities by sugar refineries. When it has served its purpose, it becomes a waste product and is sold for fertilizing. It has little value until treated with sulphuric acid. Bone-meal is the fresh bone ground and steamed and contains some nitrogenous matters in addition to the phosphorus. It dissolves very slowly.

The commercial supplies of phosphates are bones, and phosphate rocks. The latter are mined in large quantities in South Carolina, Florida, Tennessee, Virginia and Pennsylvania.

121. Nitrogenous Fertilizers. Nitrogen is absorbed by plants as nitrates. The most readily available form is the "Chili saltpeter," found in large quantities in rainless regions on the western coast of South America. As it occurs naturally in the "saltpeter beds" it contains

a large amount of salt, but when prepared for commerce it is quite pure nitrate of soda. This is the form most used on quick-growing truck crops. It is readily soluble and, therefore, easily washed out of the soil. (See ¶ 127, Nitrification.)

Sulphate of ammonia is obtained as a by-product in the manufacture of illuminating gas from coal, and from the distillation of bone in the manufacture of bone-black. It is a very concentrated fertilizer, containing about twenty per cent nitrogen. Ammonia salts may be absorbed by some plants, but they are readily converted into the nitrates by the nitrifying bacteria and are usually absorbed in this form.

122. Guano, obtained from the habitation of flesh-eating birds roosting in caves and sea islands, has long been used as a fertilizer. Dried fish, blood, hair, leather, and various other substances of animal origin, are frequently used for fertilizing purposes. The nitrogen of both animal and vegetable origin must first be decomposed and converted into nitrates before it can be used by plants. This takes time, and hence such substances are slow-acting fertilizers. The meal, or pomace, obtained as a by-product in the extraction of vegetable oils, all contain large quantities of nitrogen, such as cottonseed meal, castor pomace, germ meal obtained from corn, etc. These substances are very valuable as feeds for stock. This does not preclude their use for fertilizing, for, in fact, they are almost as valuable for fertilizing purposes, after passing through the cattle, as before.

123. Composted manures are the most economical and, in general, the most desirable fertilizers. Besides supplying large amounts of nitrogen, they contain consid-

erable quantities of potash and phosphoric acid. The vegetable matter acts very beneficially, improving the texture and water-retaining property of the soil. An instance of the power of compost to maintain the land at a high state of productiveness has already been given (¶ 115). Compost should be applied in the fall or early, winter and plowed or harrowed under. Covered barns prevent the loss in value of compost by scattering and leaching. Sometimes the compost is removed directly to the field. In many cases, where it is stored in bins, sufficient soil should be added from time to time to absorb the ammonia that is formed. When packed down closely to exclude the air, the loss from fermentation will be greatly reduced.

124. Fixation of Free Nitrogen by the tubercle-forming bacteria, found on the roots of plants belonging to the pea family, is the most important source of nitrogen known. By growing these legumes we add to the supply of combined nitrogen, and thus make the world richer. We do not recover all the nitrogen added to the soil in fertilizing. A part of it is lost by leaching, and a part by the escape of free nitrogen. All combined nitrogen may be used over and over again by plants and animals, but eventually it escapes back to the air as free nitrogen and, in this form, is available only to the bacteria which cause the formation of tubercles on the roots of legumes, and to a low class of microscopic plants. (See ¶ 127, Nitrification.) Without these plants the world's supply of combined nitrogen would become exhausted. In the present state of our knowledge, only the "tubercle bacteria," and one or two other classes of bacteria, whose life-habits are little understood, are known to have the power of fixing free nitrogen.

125. Tubercles on Legumes. Plants belonging to the pea or legume family have small tubercles on their roots. (Fig. 47, *A* and *B*.) On opening the small tubercles found
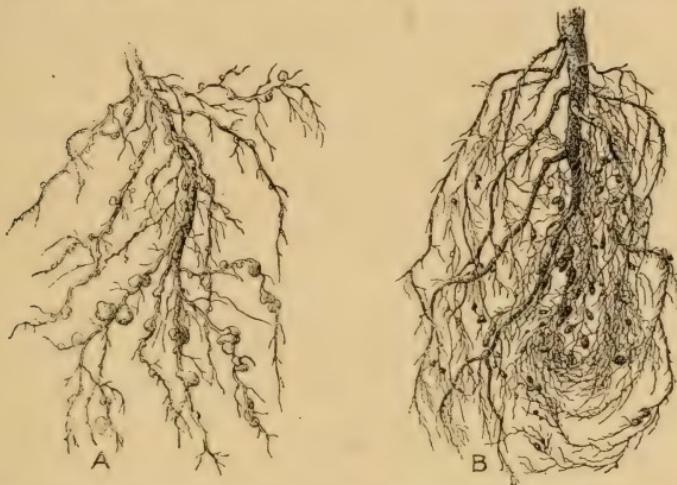
Fig. 47. *A*, root system of pea with tubercles. *B*, root system of alfalfa with tubercles. After Belzung

on the roots of beans, peas, alfalfa, blue bonnets, etc., we notice in the center a rose-colored area. If a bit of this is scraped into a drop of water, it becomes milky because of the hundreds of bacteria. They are so small that the most powerful microscopes are needed to make out their form. (Fig. 48.) It is these little plants that have the power to take the free nitrogen of the atmosphere and convert it into such form that the nodule-bearing plants, such as the cow-pea, may use it. Without these bacteria the legumes do not fix free nitrogen. It is this nitrogen-fixing power that makes these plants so valuable to us.
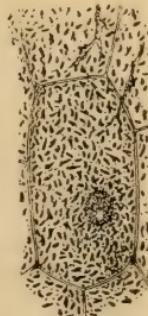
Fig. 48. Cell from tubercle of legume showing the bacteria.

126. How Legumes Enrich the Soil. By growing legumes (cow-peas, alfalfa, peanuts, etc.) the farmer is able to harvest a crop valuable as food for man, or feed for stock. These crops are especially valuable because of the large amount of nitrogenous or muscle-building substances which they contain. At the same time, strange as it may seem, they leave a larger quantity of nitrogen in the soil than was there before the crop was sown. The latter becomes available to other plants by the decay of the roots. This promotes the yield of the succeeding crop, as the following experiment shows: The plan of the experiment included two plots, "A" and "B." On "A" clover was grown the first year and barley the second. On "B" barley was grown both years. The increase in yield of barley on plot "A" over "B" is the measure of the manurial value of the roots of the clover left in the soil by the first year's crop.

Plot	Yield in first year		Yield in second year
A. Clover ...... Clover		Barley	69.4 bus.
B. Barley...... 37.3 bus.		Barley	39.1 bus.

Increase in yield due to clover roots..30.3 bus. per acre.

The fixation of free nitrogen by the bacteria in the root nodules of the pea family has been thoroughly studied and is well established.

127. Nitrification is the formation of nitrates or salts containing nitrogen. Whenever vegetable or animal remains, like guano, cottonseed meal, composts and animal bodies, decay in the soil, the complex nitrogen compounds are broken up, and nitrates are formed. Nitrogen, which is so essential to plant life, is absorbed from the soil as nitrates. The nitrogen in the cottonseed

meal, for instance, must be converted into a soluble salt before it can be absorbed. This change is complex and is brought about by certain kinds of bacteria in the soil.

128. How to Promote Nitrification. Since the amount of nitrate nitrogen in the soil affects the yield of crops, particularly grain and forage crops, the question is often asked, "Can the farmer promote the growth of the nitrifying bacteria in his soils?" The answer is "yes." These bacteria are most active when the soil is loose, so that air can enter. These bacteria use large amounts of oxygen in making the nitrates, hence deep cultivation is the first essential to promote their activity. They do not grow in strongly acid soils. (See further in any encyclopedia, under "Saltpeter.") Nitrification is most active during the summer when the temperature is high. It ceases when the temperature of the soil falls below 50° Fahr.

129. De-nitrification is the destruction of nitrates. This is due to another class of bacteria, but, fortunately, the soil conditions that favor nitrification tend to retard de-nitrification. De-nitrification takes place in a serious degree, sometimes, when manure is not properly cared for; as when it becomes too dry, or when so wet that air is excluded. The same is true for the soils of the fields.

130. How the Soil Loses Nitrogen. The complex nitrogen compounds are usually converted into nitrates and absorbed by growing plants. If not absorbed, they may be destroyed by the de-nitrifying bacteria, or leached from the soil by percolating waters. They are quite soluble and, therefore, easily washed from the soil, particularly so from fallow soils through the winter months. The practice of leaving our cotton and corn fields fallow

and unplowed through the winter has much to do with
the "wearing out" of the soils. A better plan would be
to have the ground covered by some winter annual
plant, such as oats, which could be grazed.

131. Green Manuring. Sometimes crops are grown
with no intention of saving the above-ground portion
for hay, but it is plowed under to increase the content
of humus in the soil. While, in general, it would be
much better to save the hay and, after feeding to stock,
return the compost to the soil, there may be situations
where it is desirable to turn the entire crop directly
into the soil. When a crop is plowed under to enrich the
soil, sufficient time should be allowed for complete decay
before sowing another crop. The decaying plant remains
often causes the soil to become quite acid for months
afterward.

132. Relation of Texture to Fertilizing. The profit or
loss resulting from the application of fertilizers depends
much on the texture of the soil. Irrigation water and
fertilizers are but poor and expensive substitutes for
timely efforts to improve the texture of the soil. The
best results from irrigation, or the application of ferti-
lizers, may be expected only when the soil is in the most
favorable tilth. "Tillage is manure."

133. Experiments on Soil Testing. In ¶ 117, mention
was made of the desirability of testing the value of
various fertilizing substances for any particular soil
formation. Select a level piece of soil whose productive-
ness is to be tested under varying treatments, and lay
out into beds, one (or two, or more, if desired) yard
square. The location selected should be such as to give
uniform conditions in all the beds, and all should be pre-
pared alike. Fall-sown oats, wheat, or barley, are suitable

crops for tests in school gardens. From the usual amount of the various fertilizers applied per acre, we may calculate the amounts necessary for the beds. If they are just one yard square, divide the usual quantities by the number of square yards per acre (4.840), and the quotient will indicate the amount required for the beds. It is recommended that a space of two feet be left between the beds to guard against the possibility of the fertilizer in one bed affecting results in adjacent ones. The location should be one not subject to washing or flooding.

133a. Scheme for Field Tests of Different Fertilizers. Beds exactly one yard square. Walks two feet wide.

1. Land for beds plowed......
3. Beds laid out and staked...
5. Beds planted ....
7. Depth planted ....
   ....

2. Harrowed, or raked ....
4. Fertilizers applied ....
6. Quantity of seed to each bed..
8. Plants appeared above ground

Fertilizers	At the rate per acre in pounds	Quantity of lbs. applied to one square yard	Lbs. of crop harvested
Nothing (check).............	....	....	....
Compost	5–10	2 lbs.	
Wood ashes	1,000–3,000	$\frac{1}{2}$ lb.	
Fresh lime.................	5,000–20,000	3 lbs.	
Common salt	......	1 oz.	
Sodium nitrate.............	100–300	1 oz.	
Acid phosphate	200–400	2 oz.	
Nothing (check).............	....	....	
Potash (Kainit)	100–300	1 oz.	
Combination— .			
Soluble phosphate.........	200–400	1 oz.	
Sodium nitrate............	200–300	1 oz.	
Nothing (check).............	....	....	
Combination—			
Phosphate................	....	....	
Potassium nitrate	....	....	
Nothing (check).............	....	....	

CHAPTER XIV

PRODUCTIVENESS OF SOILS

134. Fertility and Productiveness Compared. A soil may be fertile, that is, rich in food elements, but not productive because of the presence of some harmful substance in the soil. A familiar example is the "clover sickness" of northern soils. A soil naturally suited to clover will grow several splendid crops, and then become "sick of clover," as they say, because clover will not thrive any longer. The soil is still rich in all elements of fertility, but not productive for clover because of some poisonous substance thought to be produced by the decay of the clover roots. If planted to other crops for a few seasons it will recover its former productiveness. The injurious results of even a single crop of sorghum
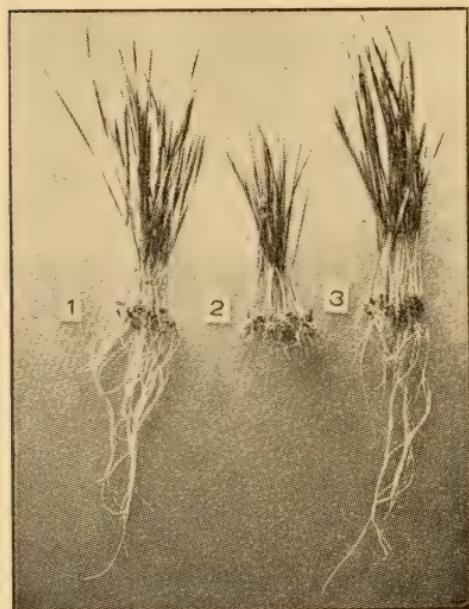
Fig. 49. Poisonous substances in the soil, formed by decaying vegetable matter, sometimes keeps a fertile soil from being productive. (Wheat seedlings grown in: (1) Pure distilled water; (2) soil extract; (3) same soil extract from which the poisonous substances have been removed by absorption with carbon black.) Bureau of Soils, United States Department of Agriculture.

on some soils is much greater than could result from the loss of fertilizing substance removed by the crop. The effect is probably due to the formation of some harmful substance by the decay of the roots. These injurious substances are dissolved in the soil moisture. Deep plowing and the application of composts tend to overcome the bad effects of the poisonous substances.

135. Soil Conditions That Affect Production. The intelligent farmer watches his crop closely from day to day, and studies all the conditions that affect the vigor or fruitfulness of his crop, of which there are many. The general health of the plant may be affected as much by conditions above the ground as by conditions below the ground. If the plants are not growing properly, close observation will often lead one to discover the unfavorable condition, and a remedy for it.

136. Excessive Droughty Conditions are noticed by wilting, twisting, or drooping conditions of the leaves. The plants endure but do not make profitable growth when this condition exists, even for a part of the day. Where irrigation is not possible, prevention is the only remedy. (See ¶ 95, 105.)

137. Wet Soil Conditions often cause the leaves and stems to grow slowly and assume a yellowish cast, with splashes of purple. This condition is not the result of too much water in the plant, but of some injurious effect of water-logged soils on the roots. Many plants can be grown to full maturity with their roots in water, but not in a water-logged soil. Soils that frequently retain injurious amounts of water should be drained. (See ¶ 107.)

138. Soils Deficient in Essential Elements. Some soils do not have enough of some one or more of the essential

elements to suit the requirements of the crop. It is important in this particular to remember that forage crops need large amounts of nitrogen, and grain crops much phosphorus. The fruit crops require much potash. A soil may be even deficient in any one or several of the essential elements. The best and safest guide to learn the special fertilizing needs of a soil is to try by test. (See ¶ 133a.)

139. Chemical Elements May Not Be in Balance. A soil may contain so much nitrogen that the crop, say
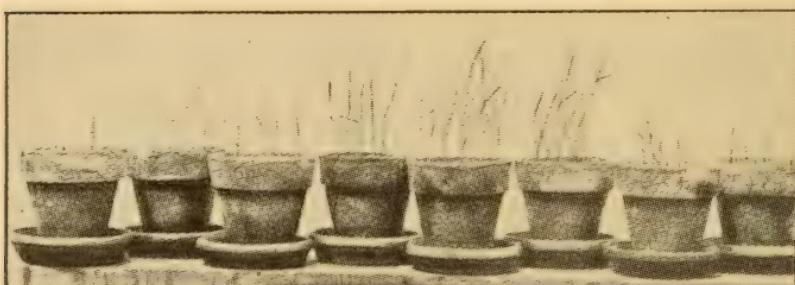
Fig. 50. Showing the effect of an excess of lime and magnesia on plant growth. Excess of lime in pots on left; excess of magnesia in pots on right. Nearly equal amounts of each in center pots. From Bull, United States Department of Agriculture.

grain or fruit, goes all to wood and leaf and does not produce a harvest. In such cases, a potash or a phosphate fertilizer would be needed to balance the ration of mineral food. Sometimes some element, even an essential element, may be in excess. Plants require magnesium and calcium (¶ 43), but an excess of either may be the cause of a poor result. Fig. 50 shows the result of adding lime to balance an excess of magnesia in the soil, and shows the effect of balanced and unbalanced amounts of calcium and magnesium on plant growth. The good effects that sometimes result from the appli-

cation of lime may be due to the establishment of balance between the calcium and magnesium as just mentioned; to the effect on insoluble potassium or phosphorus compounds (¶ 90); to a mechanical effect on the texture of the soil (¶ 73); to the effect of lime in taking up an excess of acid in soils (¶ 141); or in neutralizing some forms of alkali.

140. The Mechanical Condition of the soil may be the cause of unsatisfactory crops. Some crops, like wheat, do best with a settled sub-surface soil, while beets, potatoes and many other crops do best with a very loose soil.

141. Sour, or Acid, Soils are very unfavorable to some crops. Many soils are slightly acid, as will be found when tested with litmus paper. They differ greatly in the degree of sourness. Very acid soils are not favorable for alfalfa, cotton, etc.; but, for corn and small grains, no rule has yet been suggested. Soils that contain injurious amounts of acid are found in swamps or in sandy uplands.

141a. To Test Soils for Acid, use a small slip of litmus paper, secured from the druggist. Place the paper against the moist soil, and the color after some minutes will change. If blue, the soil is alkaline; if red, it is acid.

141½. Alkali Salts in a soil may be the cause of unproductiveness. There are several kinds of very soluble salts that accumulate in the surface soils, most frequently in regions of low rainfall. Often the dwarfing effect of alkali salts is confined to a low place, a wet-weather seep, or other place where a quantity of soil-water is evaporated. These salts are formed in all soils, but where the rainfall is abundant they are washed out of the soil by percolating water. If the rain is all evaporated from the surface, it will cause an accumulation of these salts to such an extent that injury to the plant results. Lime is often beneficial on such soils.

G

CHAPTER XV

ROTATION OF CROPS

142. Rotation. The amount of mineral food which a crop will take from the soil varies with the kind of crop, depending on how much of the crop is removed by the yearly harvest, the richness of the land, and many seasonal features which are too complex to be discussed here. By referring to the table in the appendix it will be seen that the amount of nitrogen removed by the grain crops is less than the amount removed by crops grown for their roots. It will be noticed, also, that grain crops remove or require large amounts of phosphorus; root crops, potash; and hay crops, much nitrogen; an exception being made for legumes like alfalfa, clover, or cow peas when grown as hay crops (¶ 117). Some legume crop should be included in any system of rotation.

143. Order of Succession in Rotation. It is desirable to arrange the rotation so that the same land does not have the same crop twice in succession. In arranging the crop it is important to consider the order in which the crops should follow each other. Plants with shallow roots should follow plants with deep-feeding roots; non-cultivated crops, like grain, should follow cultivated crops, because they leave the land in better tilth. As regards the predominating mineral foods, it is better to let those crops requiring large amounts of nitrogen follow potash-loving crops, or, still better, legumes, because they will leave additional amounts of nitrogen in the soil which

will be very beneficial to the grain, but not so necessary to the others. In some soils cover crops or heavy applications of fresh manure tend to cause too rank a growth of straw in the small grains. In such cases it is advisable to allow a crop of corn to come before the small grains.

144. Cover Crops; Catch Crops. Except in arid regions, it is best to keep the land constantly occupied by some crop. They not only keep the land continually earning something, but it is best for the land. A field that is bare or fallow loses more by leaching than when occupied by plants. It is often possible to grow a quick-maturing crop after the principal crops have been harvested, for example, June corn after potatoes or small grain; cowpeas after corn.

145. Marketable, or Usable, Crops. In planning a rotation or selecting a cover crop, it is necessary to consider what may be successfully sold, or used to advantage. This will depend on the markets and the farmer's facilities for keeping and feeding certain kinds of crops.

146. Other Advantages of Rotation. Besides preserving the soil nutrients, providing for their better distribution, facilitating fertilizing, rotation (which is closely related to diversification) affords other advantages:

(a) *Tends to free the land from noxious weeds*, as where oat stubble is planted to June corn, the late cultivation of the corn prevents the seeding of the weeds, such as cockle burs or Johnson grass.

(b) *Exterminates insect and fungous diseases.* Insect and fungous pests usually attack only particular kinds of crops. If the same crop is grown on the same land year after year, the larvæ of insects and spores of the fungi lodging in the ground during the fallow season will

find their food ready when the season is ready for them to multiply. (See ¶ 217 and ¶ 228.)

147. Distributes the Labor. Rotation and diversification make it possible for the work to be more evenly distributed through the year. Not all the crops will need to be planted, cultivated or harvested at the same time. The farmer will thus be able to keep busy, and not have to pay out so much for help during rush seasons that come with a one-crop system of farming.

RELATIONS OF PLANTS ABOVE THE GROUND

148. We have now found out some of the things about the relation of the plant to the soil. Soil culture, we found to be making a home for the roots. What can we do to make the conditions above the ground more favorable to the growth of the crops?

149. Provide for Leaf Development. All the carbon in plants, which is fully half their substance, is absorbed from the air by the green leaves, and, through the agency of sunlight, made into plant substance. The leaf is a part, or organ, where the raw materials are brought together and made into the foods that nourish the plant. It is plain, then, that in husbanding plants provision should be made for normal leaf development. Leaves will not grow unless plenty of light is present. This is shown when plants are grown in darkness. We have often noticed how the leaves arrange themselves so that they get the greatest benefit from the rays of light. Plants growing beside a wall or in a window turn their leaf surfaces toward the light. Vigorous leaf development is possible only when plants are far enough apart to not unduly shade each other. Too many plants must not be allowed to grow on the same ground, whether they be weeds or all of the crop planted. When the plants are too close together, the leaves and side branches do not grow, and the stem spindles up in an effort to reach the best light. The individual plants are thus weakened, and are more subject to the attack of insects

and fungi. Weak, poorly nourished plants are not fruit-
ful. Healthy plants have large leaves. Large leaves
indicate vigor. The rank-growing weeds have large
leaves. Increasing the amount of leaf surface is increas-
ing the capacity of the plant to manufacture plant
substance.

150. Relation of Leaf Surface to Soil Moisture. The
total leaf surface on a plant may be several times the
total ground surface shaded by the plant. If evapora-
tion is increased by the winds or high temperatures, it
may happen that the supply of soil moisture may become
exhausted and the plant suffer. Soils covered with plants
lose their moisture faster than if they are bare or fallow.
In regions of slight rainfall, therefore, it often becomes
desirable to reduce the number of plants to prevent too
great a draft on the stores of soil moisture. This is an
additional reason for leaving space between the indi-
vidual plants in a crop. (See ¶ 102.)

151. How Far Apart Should Plants Be Grown? Where
the value of the crop depends on the perfect develop-
ment of the individual plant, or some special part, such
as the leaves, flowers, fruits, stems, or roots, sufficient
space should be allowed that adjacent plants will not
interfere with each other. However, the value of the
crop often depends more on the total weight of the
harvest than on the quality of the individual plants.
In such cases, the loss from a limited amount of shade
will be more than made up by the increased number
of plants, as in the case of the grain crops. Again, the
fertility of the land also affects the size of the plants,
and, of course, the space which each should be allowed.
Often the use for which the crop is intended must be
considered, as, for instance, in the case of sorghum grown

for syrup or for forage; corn grown for ensilage or for grain.

152. The Vigor of Leaves and Stem Growth. The size of leaves is influenced largely by the amount of water available to the plants during the period of their formation. From this, it follows that plants grown for their leaves, like cabbage, lettuce, hay crops, etc., do best when plenty of moisture is in the ground. Light is necessary for the formation of leaves, as we have seen. Where branches are shaded, the lower leaves are small and weak, and often fall off before the season ends. As the buds, from which the branches, leaves and flowers of the succeeding season grow, are formed in the axils of the leaves and take their vigor from them, it is important that fruit trees be pruned out so that light may reach to all parts. (See Chapter XVIII.)

153. The Temperature of the Air is subject to great and often sudden variations, whereas the soil, as we have seen, changes its temperature very slowly. The above-ground portion is more often injured by extreme cold or excessive heat than the part below the ground. The first effect of lowering the temperature is to retard the growth of the plant. Cold does not permanently affect all plants alike. Some plants are killed by moderately low temperature, while others are uninjured even by long exposure to severe freezing. The ill effects of freezing are more severe on plants when full of sap. Peach trees may endure a number of severe freezes through the winter, but if a severe cold spell comes late in the spring, after the buds have swollen, the injury is often considerable.

Sometimes the bad effects are due to the sudden thawing, more than to the cold itself. The winter-killing

of the cambium layer is often confined to the east side
of a tree where the early sun rays cause a sudden warm-
ing. Delicate plants, fruits, etc., may often be saved
by protecting from too rapid thawing. By shielding
from the sun's rays, bathing in cold water, etc.*

154. Buds and Nodes. If we examine the branches of
almost any shrub or herb, we shall find that they are
divided into segments by the buds at the nodes. We have
already found a reason for calling the former nodes, and
the spaces between, internodes. The buds are formed
just above, or, as the botanist says, in the *axil* of the leaf,
which readily explains the observation that the vigor
of the buds is determined by the size of the leaves which
nourish them. The bud at the end of the shoot, called
the "terminal bud," is usually the most vigorous;
but, as a rule, the vigor and the size of the buds de-
crease as we pass down to the beginning of the season's
growth. This is often due to the subsequent shading of
the lower leaves,—often to the extent that they turn
yellow and fall off.

155. Structure and Classification of Buds. If we exam-
ine some large buds, such as the buckeye, sycamore, or
fig, just as they unfold their leaves in the spring, it
will be very plainly seen that the bud scales are only
transformed leaves, hence they are called scale-leaves
to distinguish them from normal leaves. These scale-
leaves cover up an embryo branch—a branch having
miniature leaves, nodes and internodes. Nature formed
these buds, or embryo branches, early in the preceding
season. Note also that more buds were formed than are
likely to grow into branches. (Fig. 52.)

*For excellent full discussion of the effects of temperature on plants, and
the proper treatment to lighten the bad effects, reference should be made to
Goff, The Principles of Plant Culture; Bailey, The Principles of Fruit Culture.

156. Leaf Buds and Flower Buds. If we notice the buds on peach or plum branches from January until spring, we shall see that all the buds are not the same size or shape. Some are pointed and slender, and will form a cluster of leaves when they burst forth in the spring, and are hence called *leaf buds*. Others are broad and rounded: these buds are flower buds. They are some-
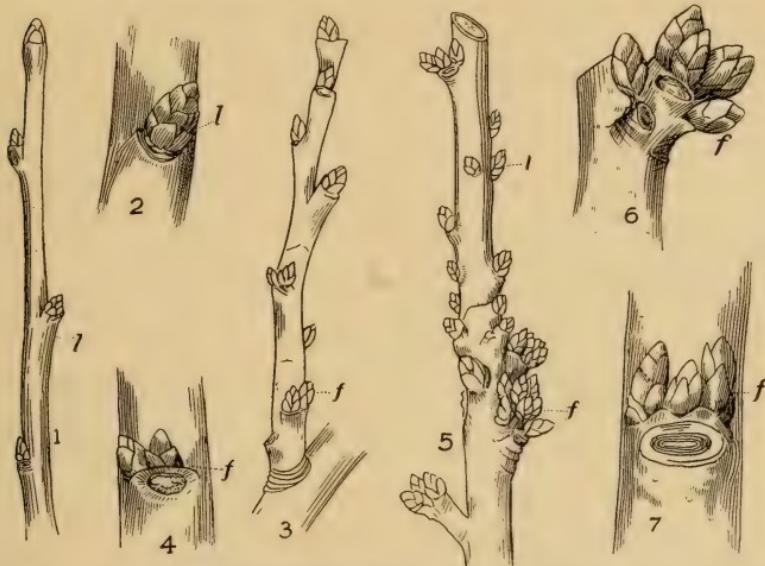
Fig. 51. Leaf buds and flower buds of plum. 1. Shoot bearing leaf-buds only. 2. A bud of same enlarged. 3 and 5. Branches having leaf-buds and flower-buds. 4, 6 and 7. Buds of same enlarged. Flower-buds at *f;* leaf-buds at *l.*

times called fruit buds, but, of course, the flower must always precede the formation of the fruit, so it is best to call them *flower buds*. Just below each bud is a leaf scar. Sometimes we will find the leaf scars, though the buds are apparently not there. They are there, however, but too small to be seen. They do not grow unless the end of the branch is removed. Such buds as do not grow except when stimulated are called *latent buds*. (Fig. 51.)

157. How to Distinguish Flower Buds. Flower buds
are formed the same season that the leaf buds are,
though it is not always easy to distinguish the two kinds
till some time after the fall of the leaves. The position of
the bud is often an indication of its kind. We notice,
in the plum twigs illustrated in Fig. 51, that the flower
buds are on the side of the leaf buds. We also noticed

that the flower buds were found
only on the wood of last season's
growth. The "bearing wood" of the
peach, plum, and other similar stone
fruits, is formed in the season before
the flowers appear. Good crops of
fruit cannot be had from trees of
this class unless sufficient bearing
wood is made the preceding season.
In the case of the apple, pear,
quince, etc., the flower buds are
formed less regularly. They occur
on the end of small side branches
that are from two to five years
old. The shape and place of appear-

Fig. 52. Diagram of a
section through a bud.
V, the apex; 1, 2, 3, 4,
successively older leaf
rudiments; *A*, *B*, *C*, suc-
cessively older branch
rudiments; *D*, *E*, vascu-
lar bundles. After Han-
sen.

ance of the flower buds vary very much in the differ-
ent classes of fruits. It is important that one should
know how to recognize them and to know the time of
their formation as well. It often gives valuable informa-
tion as to how and when to cultivate and prune. For
illustration, take the grape. The flower clusters are
found on the current spring shoots, hence we prune
heavily to promote the formation of new wood.

158. Formation of Flower Buds. In plants that are
esteemed for their flowers or fruits, it is desirable to
know all the conditions that promote the formation of

flower buds. Some sorts are naturally more inclined to form flowers than others, still we can promote the fruitfulness of the plants by giving them proper treatment. Every one has noticed that the trees bloom more profusely some seasons than others. This has led many persons to study the conditions that induce the formation of flower buds.

159. Conditions That Promote the Formation of Flower Buds. Flower buds are formed in the greatest abundance when the reserve food is considerably in excess of the current needs of the plant. If a plant is growing too rapidly, using up all the food as fast as the leaves make it, flowers are not formed in abundance. They may be stimulated to form flower buds by checking the growth, either by reducing the water supply, by removing the tips (terminal buds) of the shoots, or by restricting the growth of the roots. When plants are young, or just at the opening of spring, in the case of fruit trees, they grow very rapidly. Flower buds already formed will open, but new ones are not formed till the warm, dry winds have checked the rapid growth of the shoots. This checking of the growth allows the formation of reserve food in excess of what the plant is using for growth. *To encourage the formation of the flower buds, then, we should promote the accumulation of reserve food.*

160. How to Promote the Accumulation of Reserve Food. Experience has shown that the three following rules are safe guides:

(a) *Provide favorable conditions for food formation in the leaves.* Light and a free circulation of air are essential. These may be secured by giving the plants plenty of distance, or by pruning out useless branches. The normal healthy conditions of the foliage should be pre-

served. Plants suffering from the attacks of insects or fungi are not fruitful because they are imperfectly nourished.

(b) *Provide the roots with the proper amounts of phosphoric acid, potash, and nitrogen.* An excess of nitrogen tends to favor growth of leaves and shoots at the expense of flowers. Phosphorus and potash favor the formation of flowers and the full development of the fruit and seeds.

(c) *Check any unusual or unnecessary growth of the stems by withholding excessive supplies of water.* This check to the growth naturally results when the warm weather of the summer sets in. Where the plants are grown under glass it is often possible to regulate the time of flowering by controlling the water supply.

161. Fruiting in Perennial Plants is sometimes so excessive that they are greatly damaged. Fruit trees "overbear" to such an extent that they exhaust all the reserve food and the flower buds do not develop for the succeeding crop. This gives rise to the habit of producing a crop every other year, noticed in apples and peaches.

162. Sterile Plants, or other plants that are kept from fruiting, tend to become perennial. If the formation of fruits is prevented or removed while young they continue to grow and form new flowers. In this way, sweet peas, nasturtiums, and other plants grown for their flowers, have their blooming period prolonged. Garden plants of which the fruit is gathered immature, as beans, cucumbers and okra, grow much longer than they would if the first fruits formed were allowed to mature and exhaust the plant. Clover, grown so extensively in the North and in some southern states, is a biennial; though, if prevented from fruiting, it becomes a perennial.

CHAPTER XVII

THE OFFICE OF FLOWERS

163. We have already mentioned some of the conditions that promote the free formation of flowers. We might call it the conditions necessary for fruitfulness, for the flower is only a step in the formation of the fruit and seeds. Some plants are cultivated only for their leaves, stems or roots—as cabbages, lumber trees, or potatoes. Most plants, however, owe their value to the crop of seed or fruit which they bear. In the latter class, including the fruits and grains, it is not only necessary that the flowers be formed, but that they should form seed abundantly. They must "set seed," as the farmer says. To understand this process, we must know more about the structure and the use of the different parts of a flower.

164. Structure of Flowers. Flowers are very varied in their form, size, and in the arrangement of their parts. If we should closely examine a flower of a peach or a geranium, to take familiar examples, we will find that it has several parts, each of which contributes some service to the success of the plant's effort to form seed. We have already learned that a seed is usually an embryo plant, with a store of reserve food, both inclosed in a protecting case called the *seed coat*.

165. The Names of the Parts. We must learn the parts of a flower and their names. We first notice the brightly colored petals. They attract our attention and that of the bee also. The bee long ago learned to recognize

these brightly colored parts as sign-boards directing
it to the nectar below. The pleasant scent or odor
serves the same purpose.

166. There are five petals in the peach-blossom, all
separate, but in the morning-glory they are united.
Whether united or separate, taken together they are
termed *corolla*. (Fig. 53.) Just below the corolla there are
usually five small green leaves which are named *sepals*,
and, when taken together, the *calyx*. The corolla and
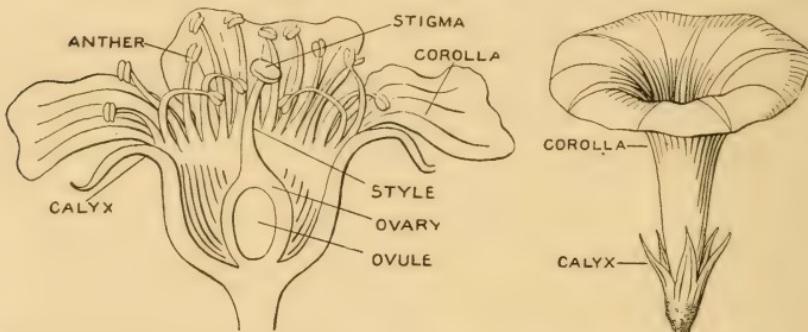
Peach-blossom cut open, to show the parts of
the flower.

Calyx and corolla of Morn-
ing-Glory.

Fig. 53. Peach-blossom and morning-glory.

calyx were called the floral envelope by the older botan-
ists. Inside of the corolla are a number of small yellow-
ish masses on slender stalks. These yellowish bodies are
called *pollen cases*, or *anthers*. When ripe, they produce
the fine yellow dust, or pollen. In the center of the whorl
of stamens is the *pistil*. There are three parts in the
pistil. At the top it usually has a slightly knob-like
portion called the *stigma*, covered with a thick, gummy
liquid. The stigma is sticky, to catch and germinate the
pollen brought from its own or other flowers. Below
the stigma is a slender portion, the *style*, and then the
swollen base, the *ovary*. The ovary is the part that

At 7 a. m.

At 10 a. m.

At 3 p. m.

At 8 a. m. the next morning.
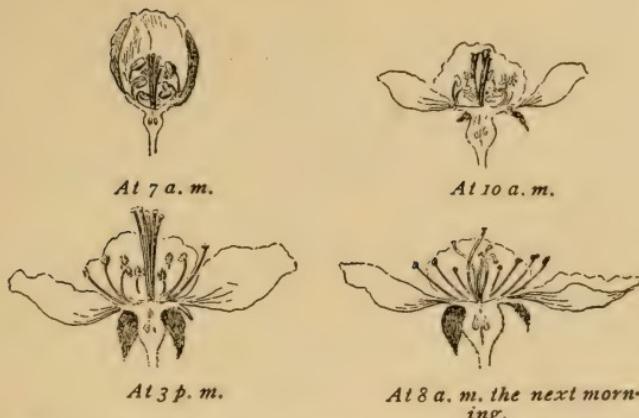
Fig. 54. The opening of a flower of Kieffer pear, showing the unfolding of the parts in blooming. The flowers of pears and apples have five styles and stigmas. All natural size. From American Gardening.

grows after the other parts of the flowers have fallen. It becomes the cherry with its seed, the pea pod, the corn grain, the pecan with hull, etc.

167. Use of the Parts of the Flower. Now that we have examined a flower and learned to recognize the parts, we want to know what these parts do. We have already learned that the bright color of the corolla serves to guide the bee or butterfly, or other nectar-eating insect, to the

Fig. 55. Flowers of scarlet sage, showing how pollination takes place. *A*, Position of anther when the bee sips nectar; *B*, stigma (*st*) in position to be pollinated.

drop of food at the base of the ovary. When the bee
enters the flower to gather bee-bread (pollen) and the
honey, or nectar, at base of pistil, some of the pollen is
lodged on its head and legs and body. When it enters
the next flower, some of this pollen is caught by the
stigma. (Fig. 55.) Many
kinds of flowers are solely
dependent on the going and
coming of insects to bring
about pollination and, there-
fore, the formation of fruit
and seed. We used to think
that flowers had their gor-
geous colors to please man's
fancy. We now know that it
is to attract the lowly in-
sects. Usually, night-bloom-
ing flowers are white and
give off their odors more
strongly at night (study the
tuberoses, rain lilies, night-
blooming cereus, moon-flow-
ers, etc.), in order to attract
the night-flying moths. Blue
and red flowers are day
bloomers.
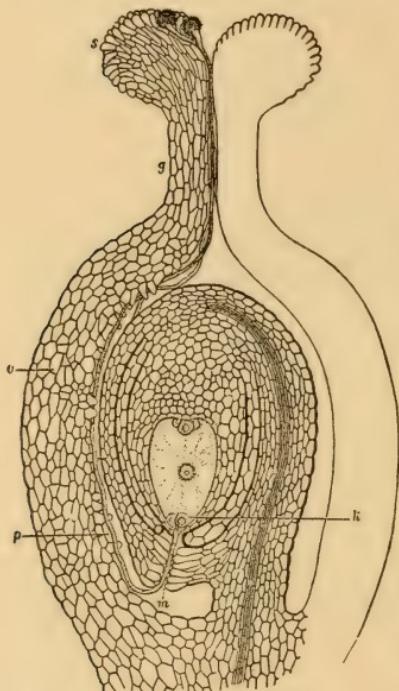
Fig. 56. Diagrammatic section of
ovary and ovule at time of fertili-
zation. *m*, micropyle; *k*, egg cell;
The pollen tube is shown down
through the style, between the
walls of the ovary and ovule, to
the egg cell, *k*, of the embryo sac.

**168. Growth of the Pollen
Grains.** The pollen grain is
a very small body, consisting of one or two cells.
When it is deposited on the moist stigma, it begins to
grow a slender tube (pollen-tube) down into the ovary.

169. Fertilization. The pollen-tube produces a small
cell that contains a nucleus that passes into and unites

A Fruit for Every Farm.
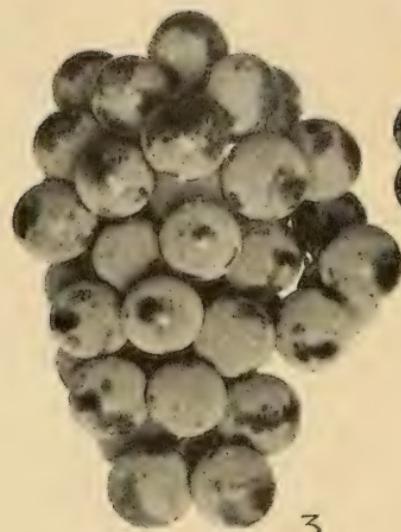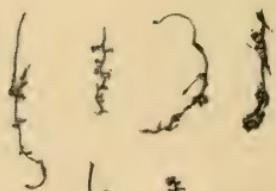
The result of pollenizing the Herbert grape with different varieties.

with the female cells in the ovule. (Fig. 56.) This process is called fertilization or fecundation. When fertilization takes place, the fruit is "set" and the ovary begins to grow. The corolla, stamens, etc., wither and fall away. If fertilization does not take place, the entire flower withers and dies in most cases,—the exceptions being the fleshy seedless fruits, as seedless grapes and oranges.

170. The Growth of the Fruit and Seeds. After fertilization, the ovary and, in many plants, other adjacent parts, begin to grow rapidly. The reserve food of the stems moves rapidly through the little twig that supported the flower into the fruit. The fruit contains the seed. Seed production exhausts the plant. Nearly all the reserve food passes into the seed and fruits. Often more than half of the substance of a plant is collected into the seeds, as in common field corn.

171. Importance of Pollination. Pollination and fecundation are necessary for the growth of the fruits and seeds, except in some kinds of seedless fruits, like the banana. In some varieties of strawberries the pollen is not produced in sufficient quantity to cause the fruit to set. In such cases it is usual to plant varieties producing pollen freely, in alternate rows. (Fig. 57.) The bees, going back and forth from one variety to the other, carry sufficient pollen to make the fruit set on the fine sorts. Some varieties of plums and pears, while producing pollen, are
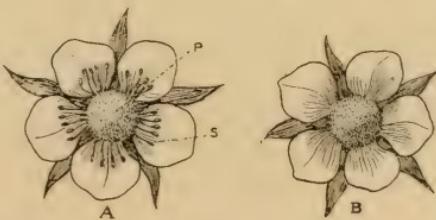
Fig. 57. Flowers of the strawberry. *A*, a flower having both stamens and pistils; *B*, flower of a kind having pistils only

H

sterile to their own pollen. Many varieties of grapes
also do not set fruit when pollinated with their own
pollen. The illustration facing page 113 shows the
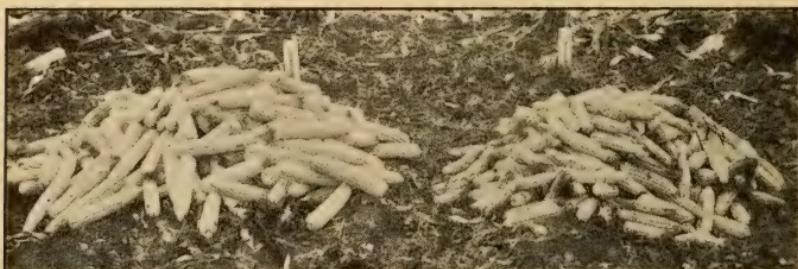
Fig. 58.   Injurious effect of self-pollination shown in pile at right. From
Bulletin United States Department of Agriculture.

effect of pollen of several varieties of grape on the
Herbert grape. Some varieties make good pollinizers
while others do not. If one is planting Herbert grapes,
other varieties should be planted nearby to furnish
pollen. In the same way, an orchard of Kieffer pears
will be more fruitful if trees of other varieties are in
the orchard. The bees will carry the pollen back and
forth as they go from flower to flower. Sometimes in
long-continued rainy weather during the flowering sea-
son a full crop of fruit is not set, because the bees are
unable to visit the flowers freely.

172. Not All Plants Pollinated by Insects. Some plants,
like wheat, oats, cotton, beans, etc., are ordinarily self-
pollinated, that is, the pollen in the flower is produced
so that it naturally falls on the stigma. Many other
plants, as the pine trees, field corn, willows, etc., are
solely dependent on the wind to carry the pollen from
one flower to another. There are many interesting
adaptations for bringing about pollination, which cannot
be discussed here.

173. Cross-Fertilization is Important in many plants. There are many plants that are normally self-fertilized and whose progeny do not seem to lack vigor. However, most plants give better seed from cross-fertilization, that is, having the pollen to come from different plants. Seeds originating from normal cross-fertilization are usually more vigorous, healthy and productive than seeds resulting from self-fertilization. The Illinois experiment station found a difference of about ten bushels per acre in the yield of corn between seed produced by cross-fertilization (Fig. 58) and that by self-fertilization.

Continuous self-fertilization leads to complete sterility in plants that are normally cross-fertilized, as corn, etc. Fig. 59. Darwin found that after eleven generations of self-fertilization the scarlet runner failed to set seed, while the plants

Fig. 59. Effect of inbreeding. *A*, Cross-bred; *B*, inbred five years.

produced by as many generations by cross-fertilization were much more healthy and fruitful than the original stock.

CHAPTER XVIII

PRUNING AND TRAINING PLANTS

174. **The Pruning and Training of Plants** have for their object the improving of the relations of the plant to the sunlight and air. They are very old arts, that were well developed before we understood how the sunlight and air were of use to the plant.

175. **The Effect of Pruning.** The practice of improving the usefulness of plants by removing some part, is founded on the principle that suppression of growth in one part stimulates growth in others. The *manner* and *season* of pruning governs the result.

176. **Pinching.** If we should pinch out the terminal bud from a leafy branch during the rapid-growing season of spring, as shown in Fig. 59, it would result in a temporary check to the lengthening of the branch and a more rapid swelling and better nourishing of the buds below. If only the tip were removed, probably only one of the buds left—the uppermost—would form a new shoot. This would soon grow out and take the place of the one removed. This pinching usually

Fig. 60. Pruning by pinching

(116)

gives a stocky growth to the branch and favors the formation of fruit-buds. (¶ 159)

177. Summer Pruning of Blackberries. If the new shoots of blackberries be pruned off, the buds below will form several branches. As the fruit of the following season will be borne on this growth, we see how summer pruning may increase the fruitfulness of blackberries.

178. Light Pruning in the Dormant Season stimulates branching. If a branch, like the one shown in Fig. 71 on page 123, were pruned at X, two, or possibly three, of the next lower buds might grow into fairly vigorous leafy branches, with many strong buds. If left unpruned, it would probably grow straight out, forming a slender shoot with very feeble side branches, too poorly nourished to form many fruit-buds. Thus we see that pruning may stimulate branching, thickening of the stems, and a freer formation of bearing wood (branches with flower-buds). This kind of pruning is often practiced on all kinds of orchard trees and berry plants, and is frequently referred to as "cutting back" or "heading-in." This kind of pruning is quite necessary for the first few seasons' pruning of newly set orchards.

179. Why Prune Plants? We see from the illustration given that pruning may be used to (1) check growth, (2) induce branching, to give correspondingly more leaf surface. The latter causes the branches to be better nourished and, hence, to grow thicker and form more flower-buds. (See ¶ 159.) Any kind of pruning that retards growth tends to increase fruitfulness and a better ripening of the branches. Pruning is sometimes objected to, with the idea that nature knows what is best for the plant. Persons who advocate no pruning forget that orchard plants are grown in an environment that

leads to an unusual development of the branches, and
that such unusual growth does not favor the develop-
men of fruitfulness (¶ 159). Practical experience has
long proven that the proper pruning of orchard trees
makes them fruitful and profitable. Pruning is not
merely removing so many branches or brush. The
pruning should be done at the place that will pro-
duce the desired result. Herein lies the value of an
understanding why and how pruning should be done.

180. Pruning to Stimulate Growth. Sometimes a
plant or tree will cease to make the normal amount of
healthy growth. If such condition is not the result of
improper soil conditions, very severe pruning of the
branches may bring about a renewal of active growth.
Very old orchard trees are sometimes improved by a se-
vere pruning. Pruning of orchard trees or shade trees
may be overdone, producing such a shock that the plant
is weakened rather
than stimulated.

**181. Pruning to
Hasten or Delay Ma-
turity.** Pruning to
hasten maturity is sel-
dom practiced except
on nursery stock (re-
moving the leaves),
or on tobacco plants.
It is usual to remove
the seed-pods from
flowering plants, such
as sweet peas, etc., in
order to prolong the
flowering period. The
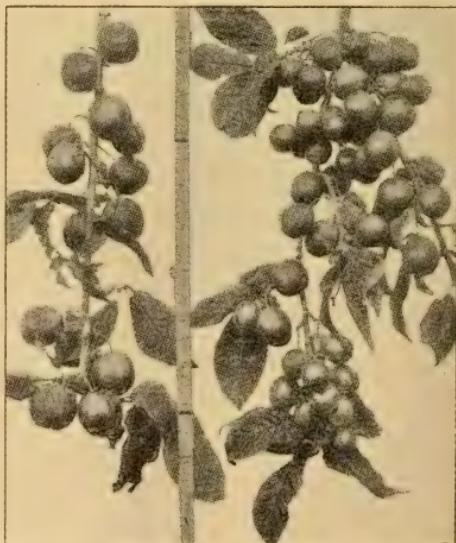
Fig. 61. An example of thinning. After Goff.

food substance that would be used in maturing the seed is used to build new flower-buds.

182. Pruning to Protect Plants from disease and mechanical injury is often necessary. Dead branches may fall and do much injury to the other limbs unless removed; or, they may become diseased by the fungi of decay and transmit the disease to the heart-wood of the trunk, thus making the plant weaker. Fig. 62. Dead or diseased branches, such as pear blight, should be cut off below the diseased part, and burned to prevent the spread of the disease.

183. Thinning Fruit is a form of pruning. It often
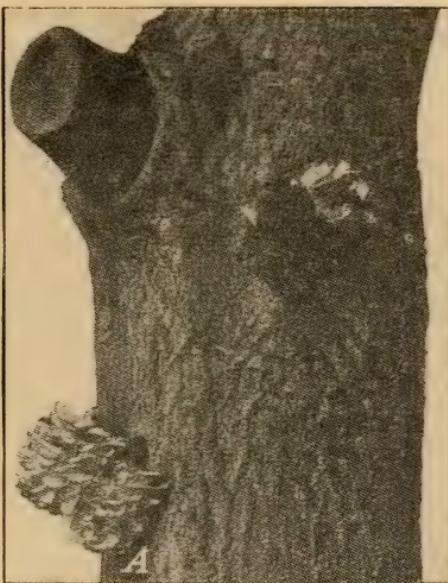
Fig. 62. Effect of improper pruning. The larger stump became diseased and the heart-wood in turn. The fungus mycelium caused the heart-wood to decay, as shown in the cross-section. The fruiting fungus is shown at *A*. From photograph by Prof. Geo. F. Atkinson.

happens that a fruit tree will set more fruit than it should mature. Nature causes many of these young fruits to fall off, but not always sufficiently. Where too much fruit is left on the branches, the trees "overbear," with the result that they do not prove fruitful in the season following. All the reserve food is used up in maturing the crop and, therefore, flower-buds are not formed. (See ¶ 159.) Another good reason for thinning is found in better quality of the fruit. A dozen good peaches will sell for more than a gallon of "pie peaches."

184. Root-pruning. In healthy plants there is a balance between root-surface and leaf-surface. If a plant is growing too vigorously, it may be checked by running a spade into the ground to sever some of the roots.
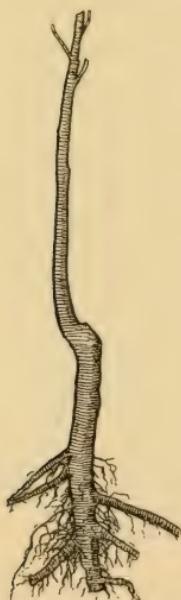
Fig. 63. Tree properly pruned before setting out
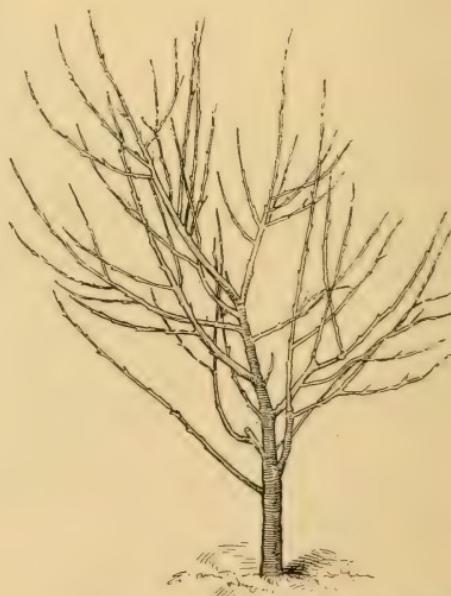
Fig. 64. A badly shaped top, due to not cutting back when set out.

185. Pruning Transplanted Plants. In transplanting plants many of the roots are destroyed, thus destroying a natural balance. Transplanted plants, especially woody ones, should have all injured and extra-long roots removed and the top cut back correspondingly. (Figs. 63 and 64.)

186. How to Make the Cuts in Pruning. When a branch is removed, we expose a part of

Fig. 65. *A*, cutting too far above the bud; *B*, cutting too close; *C*, the cut as it should be; *D*, removal of a branch, the cross-line indicating the proper place for the cut.

the cambium and woody portions. Unless this is quickly healed over, the wound may become diseased, and the entire plant, in turn, before the callus grows over the cut surface. It is important, therefore, that, in pruning, nothing but sharp instruments be used, so that the cuts will be smooth. Not only should suitable tools be used, but care should be exercised to make the cuts so that the least amount of callus will be needed to close the wound. Callus cells are nourished by the reserve food. This suggests that the line of cut should be close to the supplies of reserve food. If a small branch is to be cut off, make the cut close to a bud, as shown in Fig. 65 *C*. The bud will grow out and the cut will heal over. If cut too far above the bud, *A*, a dead stub will remain that cannot be healed over. If cut too close to the bud, *B*, the bud will die, and we have a stub the full length of the internode. Side branches should be pruned close up to the main stem, *D*.

Fig. 66. Showing proper position and angle of cut to use in removing large limbs.

Roots of transplanted plants should be severely pruned. It is not the length of the roots left that favor the plant, but the quickness with which new branches with root-hairs are formed. Severe pruning promotes vigorous branching in many plants, notably the strawberry, celery, etc.

187. In Removing Large Limbs, extra care should be taken to get the cuts at the proper place and angle.
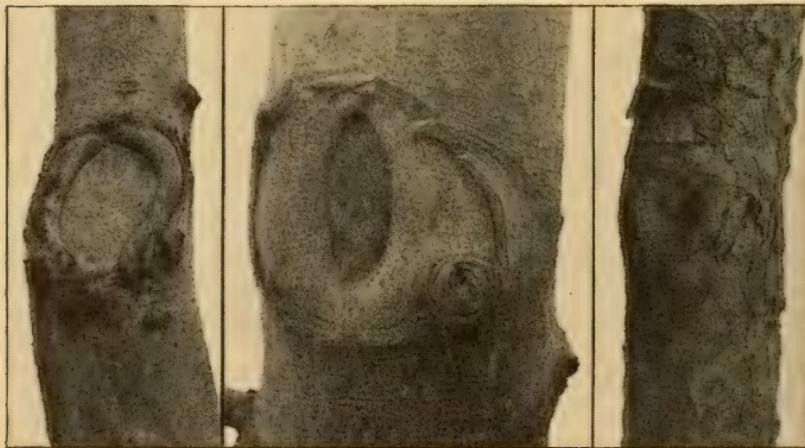
Fig. 67.   Fig. 68.   Fig. 69.
Healing of properly made cuts. Photographs by Prof. F. A. Waugh.

Figs. 66, 67 and 68 are good examples. We have already noticed the bad results from improper cuts, as shown in Fig. 62. (See ¶ 59.)

188. Pruning Orchard Trees. Before we can intelligently prune even young orchard trees, it is necessary to decide on the arrangement of the branches desired in the matured tree. Whatever the number and arrangement of the branches, they should be low enough to allow the fruit to be gathered easily, and high enough not to interfere with the easy care and cultivation of the ground. Some prefer to have the outline of the pear trees pyramidal, with a central supporting trunk, such is shown in Fig. 70. For most orchard trees, possibly for pears also, it is preferable to have a number

Fig. 70.   Pyramidal form of top.

of strong branches starting out from two to four feet from the ground. That portion from which the leading branches start is called the *head*. This gives an open center to the tree and allows more light to the smaller interior branches, and keeps even the top of the tree within reach. Fig. 71 shows the framework of an open-headed tree. Fig. 72 shows the starting of such a head,

and Fig. 73 further thickened and made stocky by "heading in." The branches should not start out from the same place, as illustrated in Fig. 74. Such branches often split out when strong winds prevail.

Fig. 71.   Open-headed tree; vase form of top.

189. Pruning and Training Grape-vines. The stem of the grape is too weak to stand without support. In nature it grows over the outer branches of trees, sometimes forming a canopy over the tops of small trees. Cultivated grapes are given supports made with posts and smooth wire. In order to keep the bulk of the vines within limits and to increase their fruitfulness, they are severely pruned every winter. This heavy pruning

Fig. 72. Starting of an open-headed tree.

Fig. 73. It is usually desirable to head-in young trees for two or three years after planting; it makes them stockier.

Fig. 74. Improperly trained. The limbs start too close together. The first big crop will split off some of them.

makes the new branches grow very vigorously, but, as the fruit in grapes is borne on the new wood, this is very desirable. (See ¶ 157).
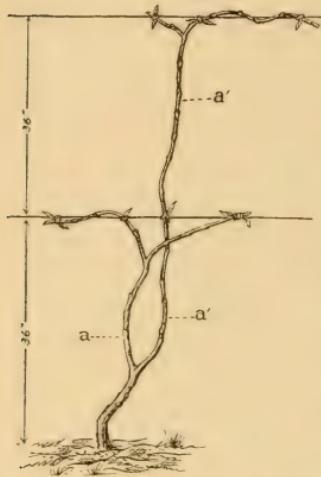
Fig. 75. Y-system of pruning and training grapes.

The growth of the vine for the first season after transplanting is cut back to a single shoot, for at least four or five feet. This is tied up to the central wire and forms the permanent stock, or stem. In pruning, after the first year, from two to four arms, or branches, are left to produce the bearing wood. The number and length of the arms will vary with the vigor of the plants. Weak-growing vines are usually left with only two or three arms.

The most desirable form of grape trellis is that shown in Fig. 76, known as the Canopy, or Munson trellis. This kind of trellis allows more leaves to be exposed to the light, and gives more color and flavor to the fruit.
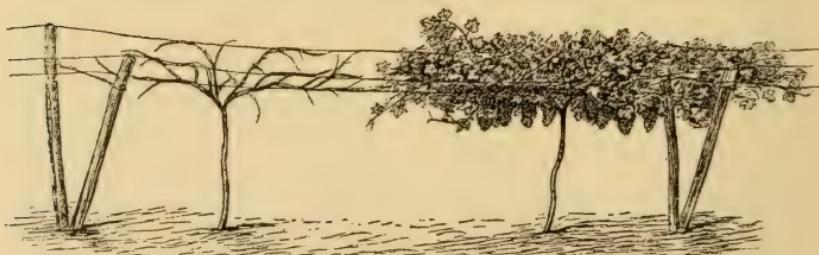
Fig. 76.   Munson system of training

CHAPTER XIX

PROPAGATION OF PLANTS

190. How Plants Propagate. Plants propagate natu-
rally by seeds and by the formation of special parts,
which become separated and independent of the parent
plant, as bulbs in onions, stolons or runners in straw-
berries, tubers (thickened stems) in Irish potatoes, and
by roots, as in the sweet potatoes, and in many other
special ways. These are natural methods of multipli-
cation, and take place without man's assistance. Often
man provides the conditions which favor multiplication
in these ways. We have already mentioned the impor-
tant conditions to be controlled in causing the embryo
plants of sprouting seeds to grow. The other natural
processes of multiplication, i. e., by tubers, bulbs, etc.,
are matters of every-day knowledge, and are used for
propagating a variety of plants. We speak of the former
as propagation by *seedage,* and the latter as propagation
by *division.*

191. Seedage. In preparing land for seeds, it is not
sufficient that the seed-bed provide simply the conditions
favorable for germination, but should be such as is de-
manded by the nature and peculiarities of the plant.
Thorough and deep pulverization is desirable for all
kinds of plants. Make a good seed-bed. It should be
done long enough before planting to allow for a thorough
settling of the sub-surface soil, for many crops, such as
wheat, corn, and other grains, do best on a settled seed-
bed. In planting, therefore, it is necessary to know the

special requirements of the crop. Quick-growing annuals and root-crops do best on a very loose seed-bed. Sugar beets become fibrous, and may be pushed out of the ground if the roots reach a hard subsoil. The depth of covering the seeds often has a great influence not only on the promptness of germination, but, also, on the fruitfulness of the crop. The distance between the seeds must be such that there is proper room for the development to the size desired at maturity, or for transplanting.*

192. Propagation by Seedage and by Division Compared. The embryos in seeds are formed by the union of the nuclei of pollen and egg-cells, each from different individuals. In division, the new individual is formed from a part of the original plant, and, therefore, has only the characters of the original plant, that is, it is just like the original plant. Seed-propagated plants often partake of the characters of two individuals. This explains why seed-propagated plants are more variable than those propagated by division. For illustration, we may use blackberries. Fig. 77 shows the forms of the leaves of a number of blackberry plants grown by Luther Burbank from seeds of a single plant. Not all seeds are so variable as the example given, but they are, in most cases, variable, and the differences are only of degree. *Therefore, in order to make sure of propagating the desirable qualities of some particular individual, resort is had to propagation by division.*

193. Propagation by Division may be by some of the

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*Note.—It is not advisable to discuss the needs of particular crops in a general text-book, but a number of interesting comparisons may be made in this connection by comparing (1) the season of seedage; (2) depth of planting and size of seed; (3) how the depth of planting affects the potato crop; (4) the duration of the roots in the soil; (5) surface feeding and deep-feeding or taprooted plants.
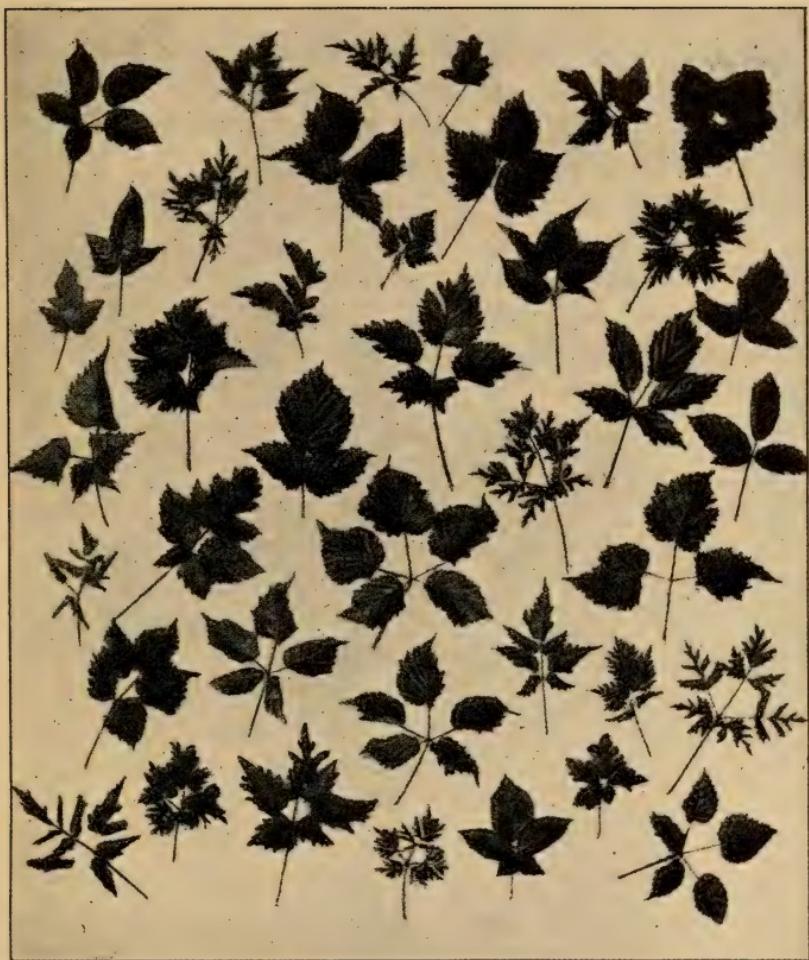
Fig. 77. Variation in leaves of hybrid blackberries, all from the seed of one plant. The stems of the plants varied just as much in shape, size and color. One result of Luther Burbank's experiments in propagation of new fruits.

natural processes, such as mentioned in paragraph 190, or by artificial processes, such as by layers or buds. The process of propagating by cuttings is known as cutting propagation. That by layers, as layering; that by inserted scions, as grafting; and that by inserted buds, as budding. They may be termed respectively, cuttage, layerage, graftage, and buddage.

194. Layerage. When a branch or part is caused to form roots, and then severed from the parent plant, the plant produced is a layer. Fig. 78 shows how a vine of
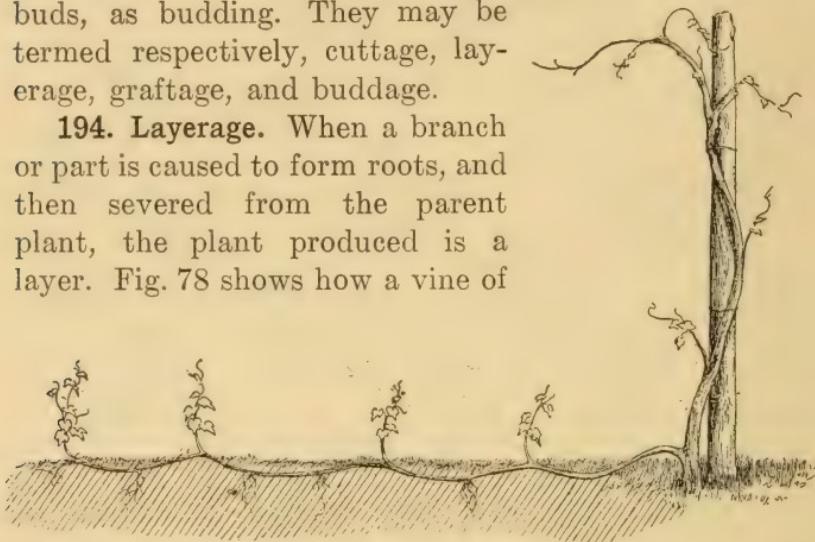
Fig. 78.   Propagating grapes by layering.

the grape may be bent down, and covered at intervals with moist soil. Roots form at the nodes. (See ¶ 68.) After these roots are sufficiently abundant, the vine may be cut into pieces, each piece having roots, and each planted in a new place as a complete plant. Layering is used to propagate grapes, raspberries, dewberries, and many other plants. Strawberries, dewberries, blackcap raspberries, and many grasses, such as Bermuda grass, Johnson grass, some of the Musquite grasses, white clover, and some varieties of sweet potatoes, naturally multiply by their prostrate stems, taking root at every node; and man, in practical agriculture,

greatly aids it by better preparing the soil. There are many plants that do not often multiply in this way, but will readily do so if their bodies or branches be bent down to the ground and covered with mellow soil.

195. Cuttage. Rooted cuttings are parts of either stems or roots (or leaves, in some cases), cut into small pieces and kept under proper conditions until the formation of roots and shoots has taken place. Cuttings of some kinds of plants put out roots very readily, as willow, dogwood, roses, grapes, some kinds of plums, and berry plants. Cuttings may be made from dormant or green

Fig. 79. Cuttings: *a*, simple cutting; *b*, heel cutting; *c*, mallet cutting; *d*, single-eye cutting.

growing shoots. Geraniums are propagated from green cuttings. Green cuttings should be kept moist at all times.

196. Buddage. The callus-tissue of one plant may unite with the callus-tissue of another plant, if the two plants are of the same kind. Apple may be made to unite with apple; peach with peach; but not peach with apple. However, peach will unite with plum, because peach and plum are closely related. In budding we have two parts: (1) A *bud* of the kind or variety to be propagated, and (2) a *stock*. The stock may be a rooted cutting or a seedling. In the common "T"-budding, a sharp

knife is used to make a "T"-like slit through the bark, as shown in Fig. 80*D*. The corners may be raised and a bud, cut as shown at *E*, placed under the edges of the bark of the stock, as shown at *G*. The cambium layer of the bud is left in contact with the cambium layer of the stock. The wound is wrapped with soft twine, such as cotton yarn, or other suitable material, to hold the edges of the bark down and keep the bud from drying out as at *I*. After a week or ten days, depending on the condition of the shoot, the bud will be grown to the stock, if the work has been properly done. In this way we may cause one variety of plant to unite with another. Budding is easiest made and most likely to be successful if made while the stock is growing rapidly, or when the bark "slips," as it is called.

197. Later Care of the Bud. After the bud has united with the stock, there is still much to be done before we have a new plant. The strings are removed when the bud has united with the stock. The later condition is shown by the bud remaining green and plump. After
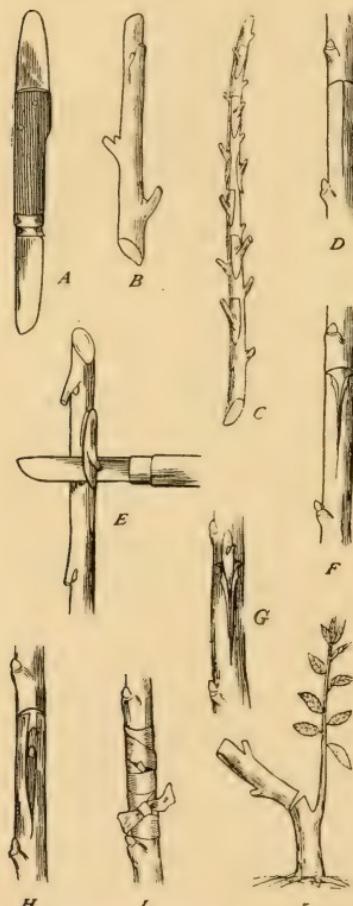
Fig. 80. Steps in propagating plants by budding

a week to ten days, or when the string begins to be over-
grown, it should be cut and removed. The next step
is to force the bud into growth. This may be done im-
mediately, as in "force budding," or left until the fol-
lowing spring; when the top of the stock is cut off just
above the inserted bud. This causes all the buds below
to swell and many to form shoots. All the new sprouts
except the one from the inserted bud should be rubbed
off when they attain three to five inches in length. This
causes the new shoot to grow very rapidly. Many per-
sons leave a foot of stock stem to protect the young
shoot. As soon as the latter is thoroughly established,
the stock is pruned close down, as shown in Fig. 80J.
The final result is that we have a stem of one variety
growing on a common seedling stock. One may prop-
agate millions of Elberta, or other variety of peach
trees in this way, and every tree will bear peaches just
like the parent variety. The great value of propaga-
tion by budding is obvious. Choice varieties of peaches,
plums and apricots are propagated by budding. It is
often used for pears, apples, roses, and many other
kinds of plants. Special methods of budding are used for
pecans and other hardwood trees.

198. Graftage. In propagation by grafting, two parts
are used, as in budding. One we call a stock, or root, and
the other the *scion*, the latter coming from the plant to
be propagated. The scion usually consists of a short
piece of stem. In making the *cleft-graft*, the stock is
split open smoothly, as shown in Fig. 81A. The lower
end of the scion having been trimmed to a wedge is
inserted as shown at A. Care should be taken to
see that the cambium layer of stock and scion coincide,
at least on one side. (Fig. 81C.) The graft is now wrapped

with waxed cloth to prevent drying out. The two layers
of cambium grow and unite, and the scion grows out into
a vigorous shoot. Cleft-grafting is used in propagating
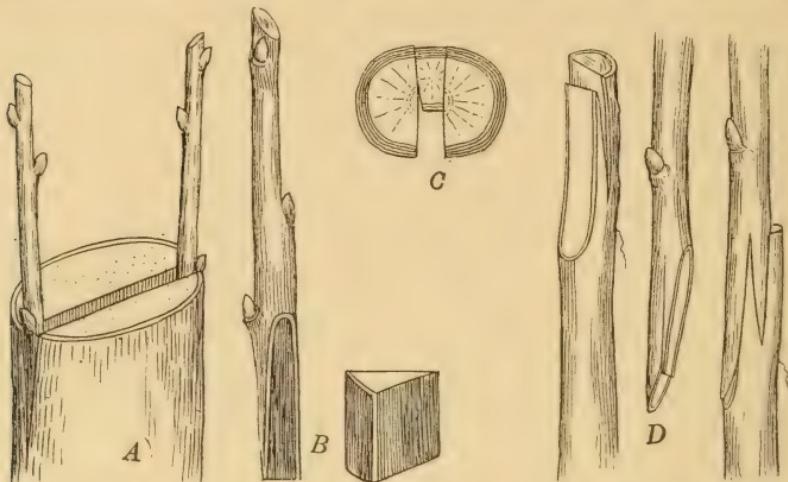
Fig. 81.   Steps in propagating by graftage. *A*, *B*, and *C*, details of cleft graft;
D, same for tongue graft.

many kinds of plants, such as apples, pears, peaches,
etc. If the graft is made below the ground on a rooted
stock it is not necessary to wrap with waxed cloth. The
moist soil, pressed firmly about the union, prevents
drying out.

199. In Tongue Grafting, we make a sloping cut on
both scion and stock. (Fig. 81*D*.) The tongue of one
is slipped into the cleft of the other, care being taken
to have the cambium layers together, at least on one
side. In piece-root grafting, as is usual with pears and
apples, the graft is wrapped to secure the two pieces in
an unmovable union until the callus growth has had
time to unite. They may be prevented from drying out
by storing in moist sand or sawdust. It is usual to make
the grafts during the winter months and plant them in
the nursery rows early in the spring. (Fig. 82.)

200. Care of Buds and Grafts. There are many special ways of budding and grafting. All depend on the property of callus-tissue of two different plants to form a close living union. In making the cuts, nothing but the sharpest of knives should be used. Dull knives produce such mutilation that the cambium does not grow out and form the callus-tissue promptly, and, as a result, the graft or bud fails "to take." The dormant buds on the stock are inclined to form vigorous-growing sprouts, but should be rubbed off as explained in ¶ 197.

201. Transplanting Nursery Trees. Nursery trees, whether propagated from seeds, cuttings, buds, or grafts, are removed from the nursery rows and trans-
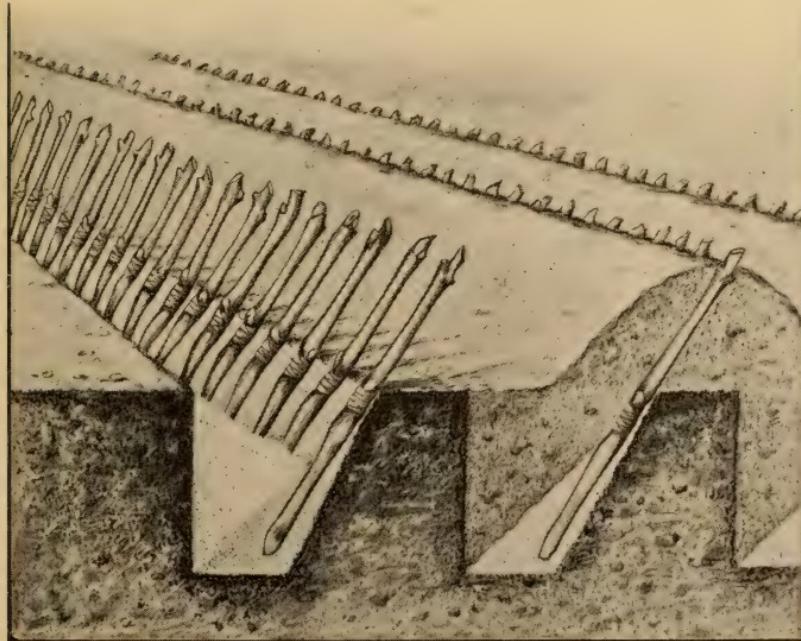
Fig. 82. Grafted cuttings set in nursery row.

planted in orchards. In removing nursery stock, many of the roots are necessarily cut short. In transplanting, the ends of all bruised or mutilated roots should be cut off smoothly and the top cut back to keep it in balance with the roots. Fig. 63 shows a one-year-old budded peach tree trimmed ready for transplanting. The young trees should be put into good-sized holes and loose, moist soil worked in around the roots, and tramped just sufficiently to hold the young tree in position. In transplanting nursery stock, the roots should never be allowed to become dry.

IMPROVING PLANTS AND SEEDS

202. Domesticated Plants. The cultivated plants were originally wild sorts. Some of them have been cultivated so long and so improved by man's care that the original or wild form is not certainly recognized, such as wheat, potato, onion, cabbage, etc. Other sorts have been brought into cultivation in comparatively recent times, and the original wild form is well known, as the tomato, carrot, chrysanthemum. Cultivated forms are vastly superior to the wild forms. The strawberries of our gardens are more palatable and productive than the wild sorts. The cultivated tomato is much larger and firmer than the original wild form. Wherever a plant has been long under cultivation it has been greatly modified. We may ask, "How are these improvements secured?"

203. Variation in Plants is the starting point for improvement. Scientists have a theory that all the plant and animal forms descended from some common ancestor. This theory of the origin of living forms, called the "theory of evolution," finds its support in the similarity of many forms, suggesting relationship, and the further fact that, through natural variation, new forms are constantly

Fig. 83. Old-time and new-time forms of tomato. After Bailey.

(137)

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205. "Natural Selection." The original wild species owe their form and habits to the continuous selections which wild nature makes. Wild plants must grow in competition with other plants and struggle with them for the conditions necessary for growth and the preservation of their seeds. The size, form and character of the leaves, stems, flowers, fruits and seeds, are all important features in the struggles for nature's favors.

206. No Improvement Without Variation. No two plants are exactly alike. The offspring from the same individual are not alike. This is the fact of "variation." In some forms the variations are more obvious than in others. As a rule, variations in wild plants are less frequent than in cultivated forms. Variations may be desirable or undesirable and progress comes from propagating only the best selections. Improvements could not be made if all individuals were alike.

207. Variations Are Not Permanent. The Concord grape is a variation of the wild fox grape of Massachusetts, discovered by E. W. Bull about 1850. It has been propagated by division ever since and is still the same grape, because our Concord grape-vines of today are only parts of the original plant. However, when the seed of Concord grapes are grown, we get the original wild fox grapes. Many such seedlings have been grown, but none have yet been secured that are the same as the parent vine, although some of them are very nearly like it. DeVries had a variety of corn, the ears of which had eight to twenty-two rows of grains. The average number of rows was between twelve and fourteen. He planted an ear having sixteen rows and found the average in the crop to be fifteen rows per ear. He then planted some ears having twenty rows and continued this for

six generations. At the end of this time the average of the variety was twenty rows, whereas it had originally been only thirteen. The lowest number of rows on any ear was twelve and the highest twenty-eight, a number that had never been observed in the parent variety. The average and the actual number of rows had been greatly increased by continuous selection through six years, yet, when left for three years without selection, the average number of rows was back to thirteen. Other instances might be mentioned, showing the inconstancy of varieties propagated from seed.

208. Perpetuating Desirable Variations. How may a desirable variation be perpetuated? There are two ways: (a) *Propagating the Plant by Division.* (b) *By Repeated Selection toward an Ideal Type.* Many kinds of plants are more conveniently propagated from seed, such as the grains, cotton, garden vegetables, and the like. We have seen how the number of rows of grains on an ear of corn was increased. Had the selections been continued for ten or more years, the new characters would have been more fixed.

(c) *Special Methods.* In addition to continual selection, plant-breeders sometimes resort to inbreeding to fix variations. Plants that normally inbreed, like oats, wheat, cotton, and others, are much less variable than kinds that are normally cross-fertilized, as corn.

209. How to Stimulate Variation. While seed-propagated plants are variable, in fact too much so for the average grower, the plant-breeder desires to bring about the most decided variations possible in the hope that some form of unusual value may be secured. The means usually relied upon are:

(a) *Intensive Culture.* Plants grown under the most

favorable conditions are thought to produce a more variable offspring than wild or uncultivated plants.

(b) *By Hybridizing Dissimilar Forms*, such as different varieties, or species. Many valuable varieties of fruits have been secured by cross-fertilizing individuals belonging to two different species.

We have already noticed the variations in hybrid blackberries (¶ 192). As a rule, the more dissimilar the parents, the greater are the variations in the seedlings. In choosing parents for hybrids, it is well to consider the characters of each; for it is possible, though often quite difficult, to combine the good qualities of two forms in a single individual.

210. Some Notable Results. Professor Munson found that the varieties of the wine grapes, grown with such success in Europe, and the fox grapes, in the eastern United States, were not suited to the climate of the Southwest. He sought to combine the hardiness of the native wild grapes of Texas with the fine flavor and fruitfulness of the foreign species by hybridizing. Many valuable varieties of grapes well suited to Texas conditions have been produced in this way. Some of the most popular are the Carman, Fern, Muench, and America, each having one-half of the native Post-oak grape blood. The Kieffer pear is a hybrid between the Bartlett and Chinese Sand pears. The Bartlett pear has a delightful flavor but often suffers from blight. The Sand pears are poor in flavor but quite hardy and fruitful. Many fine varieties of plums, blackberries and dewberries have been produced by hybridization.

211. Hybridization is accomplished by placing the pollen of one variety or species upon the stigma of another. To prevent self-pollination, the anthers should

be removed before the pollen is mature. (Fig. 85.) In the flowers of wheat, oats, peas, and some grapes, pollination takes place before the flowers open; hence, in such plants it is necessary to remove the anthers very early.

Fig. 85. Buds or "squares" of cotton. 1. Flower-bud nearly ready to open; 2, parts removed to expose the stamens; 3, stamens removed to prevent self-pollination. After Hartley, United States Department of Agriculture.

After the anthers have been removed, the stigma should be protected from chance-flying pollen by covering the flower with a paper bag. The sack may be removed when the pollen is to be placed on the stigma. The latter may be accomplished by a clean, moistened finger, camel's-hair brush, or other means suited to the plants in hand. For success in artificial cross-pollination, one should fully understand the structure and habits of flowers in both parents.

212. The Hybrid Seedlings. The seedlings from hybrid seed should be closely observed. Out of a great number of individuals, only a few, possibly none, will possess the desired characters. Even though none are found, it is often desirable to grow their seed in the same way for the desired form may appear in the second generation.

When a specimen is found having merit, it should be
given special care and properly propagated (¶ 208).
When a new form is secured and has its characters so
fixed until they "come true," it is called a variety.

213. Examples of the Value of New Varieties. The
improvement of our cultivated plants has been gradual
because but few men have made it a business to look
for and select out the best forms. Many men, however,
have secured decided results in a few years by following
scientific methods. The work of Professor Munson has
already been mentioned. Hays was able to secure a
strain of Minnesota blue-stem wheat that produced
five bushels more per acre. When wheat is worth 80
cents, such seed represents a superior earning value of
$4 per acre. Many other examples of the great value

Taylor   Iron   Black

Fig. 86. Iron cowpea vs. Black and Taylor, showing comparative resistance to
the Wilt and Root Knot. From Bulletin United States Department of
Agriculture.

of propagating seed from desirable individuals might be given. The old varieties have, in many cases, been crowded out by the introduction of new and better forms. Special attention should be called to the Elberta peach, many excellent varieties of grapes, Austin dewberry, Gonzales and other varieties of plums, Triumph cotton, and other forms that have added immensely to the value of the harvests of the world's staples. A variety of the cowpea has been discovered that is not only resistant to "wilt," but to the little worm which causes the formation of knots on the roots of other varieties.   (Fig. 86.)

213a. Selecting Seed Oats.* Suppose that it is desired to improve the quality and yielding power of oats. The first question to be answered is, "What quality has the oat that makes it valued? For what may the oat plant be used, and what does it supply?" In the South it is sown in the fall and the field is used for winter grazing. It makes a crop of grain which is thrashed and the straw and the grain are both used. The grain has most value so that in selecting oats we usually select for fine grain.

Next let us find out what an oat grain is. If we carefully hull an oat grain we find a hull composed of two or more pieces, and a true seed. If we examine a number of large grains we shall find that the large grain usually has a large seed. In selecting the seed then we will select the large grain. Now secure a bundle of oats harvested and bound just as they come from the fields. Let each student take a dozen heads as they come, spread them out on a table and note

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*The foregoing outline of the process of selecting seed oats and suggestions for testing the qualities in the plants of the progeny is given merely to illustrate the more fundamental problems of seed improvement, and the common crops or garden plants. They may be carried out by any energetic boy or girl in a corner of the garden with noticeable results in improving the plants. As an exercise for training the mind in observation, comparison, discrimination, and test of ideas, it will prove highly satisfactory to the teacher from the viewpoint of culture training as well as a practical study in "the relation values." Oats have been selected because they may be grown and matured during the school year. Local conditions may suggest other material. Some consideration should be given to the more important crops of the community, such as corn, cotton, kafir corn, sugar-cane, rice, and the various kinds of fruits.

the differences in the heads. Now thresh out each head separately and put the grains from each head in a small bottle. Note differences in color, size, shape, etc. What sorts do you consider the best oats? Why? Save the four best and take home and plant one seed at a time in drills one foot apart, and one foot in the drill. Plant seeds from each head separately, so that if they grow differently it may be noticed. Compare the quality of the crop from the four different heads. If the school has a school garden they may be planted there.

214. Effect of Cultivation. Cultivated plants are shielded from competition with other plants; they are planted in prepared ground, given plenty of space, and protected from many destructive agencies; their seeds are harvested, stored, and throughout the life of the plant they are given favorable opportunity to make vigorous growth. Cultivated plants are selected, not for their ability to propagate under unfavorable conditions, but because of their power to grow and fruit under favorable conditions. Wild plants do better under cultivation, but not in the same degree that improved varieties do. In selecting seeds for propagation, preference should be given to the forms which show the greatest yield under favorable but practical condition. The local conditions, whether due to peculiarities of climate or conditions produced by culture, often affect the result quite as much, possibly more, than the kind of seed. A variety may yield very satisfactory harvests in one place, and yet be quite unsuited to other localities or uses. It has been found to be quite generally true that when equal care is given to seed selection, home-grown seeds are better yielders.

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CHAPTER XXI

FUNGUS DISEASES OF PLANTS

215. Many plants of the farm and garden are subject to attack by various kinds of minute plants, known as fungi. The "rusts" of small grains, plum trees and cotton, are familiar examples. Also, the "mildew" of grapes and roses. These fungi are thread-like plants. Some form their thread-like bodies *inside* of the plant tissues, such as the "smuts" and "rusts." (Fig. 87.) Other forms, like the mildew, grow on the surface of the leaves and stems, but send little root-like branches (Fig. 89) into the plant tissue to absorb its substance. Another class of fungi, known as bacteria, never form "threads," or *hyphæ*, as they are called by the botanist, but only cells. Some species of bacteria cause disease. The cells are formed *inside* of the plant body.

216. How Fungus Plants Get Their Food. Fungi do not have the green chlorophyl (¶ 48),

Fig. 87. *A*, head of oats affected with smut, the chaff being only partially destroyed; *B*, head of oats decidedly smutty, but having the chaff only partially destroyed; *C*, final stage of oat smut, showing condition at harvest time

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and, therefore, can not make their food like the algæ and the higher green plants. They are called dependent plants. There are many kinds. Plants like the fungi are thought by scientists to be greatly changed algæ that have lost
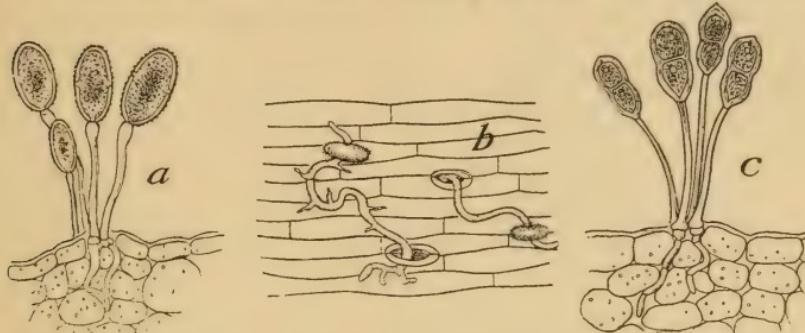
Fig. 88. Spores, or seeds, of the fungus producing the "rust" of wheat. *A*, summer spores, or "red rust" stage; *B*, same germinating on surface of leaf; *C*, autumn spores, or "black rust" stage.

the power of carbon assimilation, and are, therefore, dependent on host plants to supply the food they need. They are called independent plants. Many higher plants are dependent in the same way, such as the dodder, or "love vine." They grow under many conditions, but all must get their food from plant or animal substance. Species that get their food from living plants or animals, are called *parasites*. Those that get their food from dead plant or animal remains, are called *saprophytes*. Some species of fungi may get their food from either living or dead organisms. The red or black powdery mass which we call "rust," is only a mass of *spores* (one-celled seeds) of the fungus causing the disease. The body of the plant exists as a lot of threads inside of the host-plant and is not visible to the eye. When magnified by the microscope, these fine hyphæ may be plainly seen.
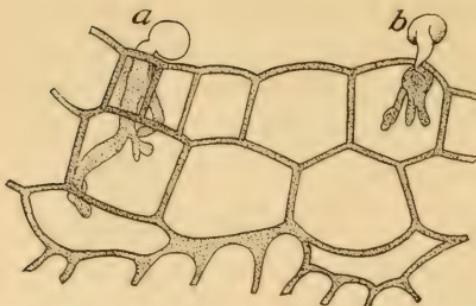
Fig. 89. Germinating spores of the potato blight fungus. Cross section through a portion of a stalk. Two germinating spores (*a*, *b*) piercing the epidermis, and the threads penetrating the cells of the leaf.

217. How Fungi Propagate. Fungi propagate by minute cells, called *spores*. They correspond to seeds of higher plants. They require the same conditions for germination as seeds. Fig. 89 shows a spore of the potato blight germinating on a leaf. The first thread soon enters the plant and absorbs the moisture and food substance of the potato leaf. It soon forms a crop of spores, sometimes in only a few days. These spores are blown to other plants, and soon a whole field will be blighted by the fungus. Most species of fungi grow on only one kind of plant. The fungus that causes grape mildew (Fig. 90) does not grow on any other kind of plants but grapes. The fungus that causes the blasting of the ears and tassels of corn (corn smut) grows only on corn. The fungus that causes the smut of oats never attacks corn. However, the fungus that produces the rust on grains also attacks

Fig. 90. Downy mildew of grape (*Plasmopora viticola*), showing tuft of gonidiophores bearing gonidia, also intercellular mycelium. After Millardet.

barberry bushes. A number of fungi known as "rusts" have more than one host-plant. The yellow rust of apple leaves is the same fungus that produces the so-called cedar apples on cedar trees.

218. Not All Fungi Cause Disease. Some fungi are very useful, like the little bacteria that gather the free nitrogen of the air for beans and clover plants; the yeast, used in making bread, and in making wines and beers. Some fungi are quite large, as the mushrooms and puffballs. Certain kinds are highly esteemed as table delicacies, and are cultivated. Some species of mushrooms should not be eaten because they are poisonous.

219. Preventing Fungus Diseases. There is no cure for the fungus diseases in plants. Prevention is the only safeguard against loss from parasitic fungi. This is accomplished in four ways:

(a) *Treating the Seeds* with substances that destroy the disease-causing germs, as scab in potatoes, smut in oats and wheat.

(b) *Using Resistant Varieties.* Not all plants are equally subject to the attacks of parasitic fungi. Some varieties are much less injured than others. (Fig. 86.) Many varieties of cultivated plants owe their value to their power to resist disease.

(c) *Sanitation.* When crops are subject to a particular disease, all the dead parts, trash and litter that harbor the spores, should be gathered up and burned.

(d) *By Using Fungicides.* Fungi are poisoned by extremely small amounts of copper salts, or sulphur in some cases, while green plants are not affected by small amounts. Preparations of copper salts in water are, therefore, used to spray plants to protect them from attacks of fungi. A compound of copper sulphate (blue
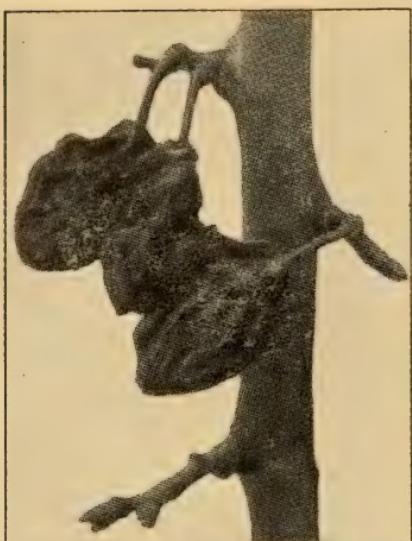
Fig. 91. The "brown rot" of plums and peaches leaves "mummies" on the trees.
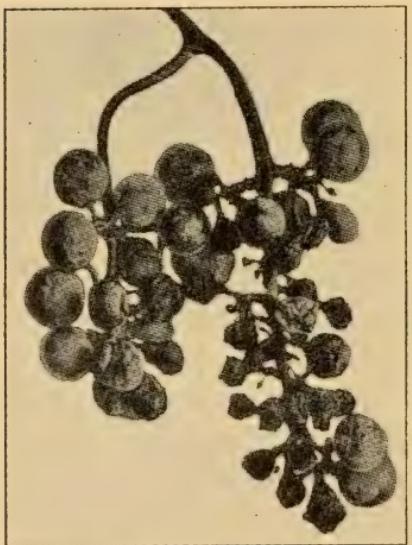
Fig. 92. Black rot of grape may be prevented by timely use of Bordeaux mixture

vitriol) known as Bordeaux mixture (given in the Appendix) is most often used. The plants are sprayed with a very dilute solution, so that a thin film of the poison covers the leaves, stems, buds, and fruit of the plant. Spores on the surface of thoroughly sprayed plants are killed, as likewise others that fall on the plants. It is often necessary to make several applications, to replace the film of spray washed away by rains. Sulphur, formaldehyde, and other substances, are used for special diseases.

220. General Methods in Using Sprays. Where efforts are made to prevent the attacks of fungi by sprays, it is important to know how and when infection takes place. No general rules can be given. The time and manner of applying the fungicide must be suited to the conditions peculiar to the

disease. The agricultural experiment station bulletins and special books on spraying will supply full information.

221. Diseases of Orchard Fruits, such as brown rot of peaches and plums (Fig. 91); mildew and black-rot (Fig. 92) of grapes and other common diseases are controlled by spraying with Bordeaux mixture. The first spraying

Fig. 93. The apple scab may be prevented by spraying.
From Cornell University Junior Naturalist.

should be before the buds swell, and repeated every few weeks thereafter until the crop is safe.

222. Grain Smuts. The smuts of oats and wheat (Fig. 87) may be prevented by treating the seed before planting. The spores become lodged on the grain on the hull or fine hairs. When the seeds are planted, the spores germinate with the seed. It is peculiar, but true, that this fungus can infect the plant only in the seedling stage. Therefore, it is plain, that to prevent the blasting of the oats by smut, we must destroy the smut spores on the seed before planting. This may be done without injury to the grain by treating the seeds with dilute

solutions of formaldehyde, or other special preparation.*

223. Potato Scab may be prevented by soaking the seed potatoes in a two- or three-per-cent solution of formaldehyde for one or two hours. This destroys the fungus in the scabs and cracks on the potatoes.

224. Cotton-root Rot is a serious disease of cotton on heavy clay lands. The disease does not attack cotton on loose, sandy soils. This fact has suggested the practice of early and deep breaking of land to prevent the growth of the fungus. Results are favorable to the practice. Rotation is also a means of holding this disease under control. The destructive effects of the cotton-root-rot fungus is often confused with damage due to alkali. The soft, spongy condition of the roots of plants killed by this fungus is very characteristic. This fungus also attacks okra, orchard trees, shade trees, etc., in fact nearly all classes of plants except members of the grass family, such as corn, small grains, sorghum, etc.

*See full directions in Farmers' Bulletin No. 250, United States Department of Agriculture.

CHAPTER XXII

INSECTS ON THE FARM

225. There are a great many kinds of insects found on the farm, many of them useful, while a few kinds are injurious because they feed on the plants and animals of the farm. Not all the small animals are properly called insects. Insects have just six legs, and their bodies are made up of three parts that may be easily distinguished: First, the head; second, the thorax, or middle part; and third, the abdomen. The spiders, mites and scorpions have eight legs. The common sow-bug has twelve legs and is more closely related to the crabs and craw-fish than to true insects.

226. Changes of Form in the Growth of Insects. Nearly all species of insects have several forms in passing from the egg to the mature insect. It is like the story of "The House that Jack Built." The female lays the egg; the egg hatches into the larva (caterpillar, grub, or maggot);
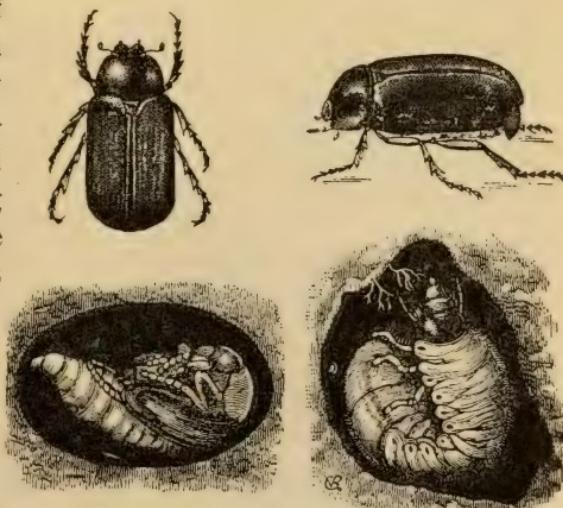
Fig. 94. Stages in the life history of the June-bug. After Howard Division of Entomology, United States Department of Agriculture.

(153)

the larva feeds and grows and turns into a chrysalis, or pupa, and out of this comes the mature insect again. Take the common May-beetle, or June-bug as an example. (Fig. 94.) The adult lays the egg among grass roots in the early spring. From this then hatches a small larva (white grub, or "grub-worm"), which feeds on the roots in the soil. It grows rapidly, and, at the end of the second season, goes into a dormant state and changes into a pupa, and, at the end of two years, emerges from the ground as a May-beetle, or June-bug. In the larval stage, the June-bug often does much damage to the roots of grasses, corn, wheat and garden plants, while the adult feeds on the leaves of trees—often fruit trees.

The caterpillar stage in insect development is quite unlike the mature butterfly stage, and only the closest watching of the life history of the "wiggle-tail" convinces
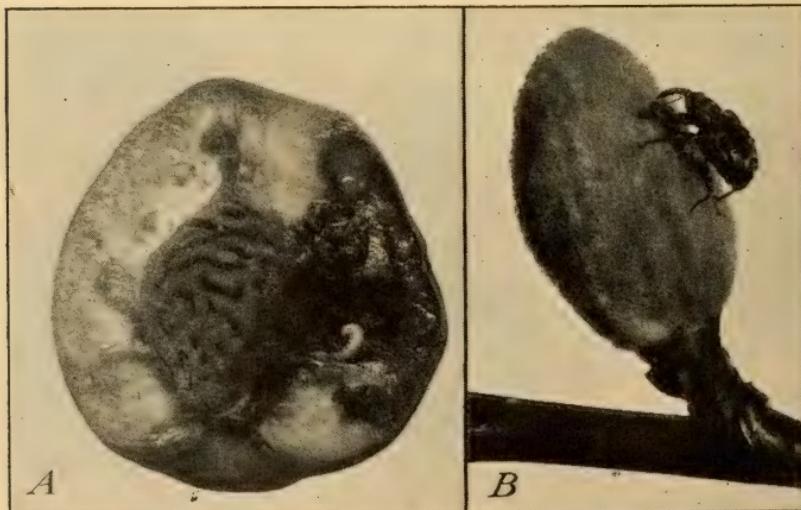
Fig. 95. Plum curculio. 1, larva inside of peach; 2, mature insect depositing egg. After Quaintance, United States Department of Agriculture.

us that it is a mosquito in another form. The little "worm" (larva), found in the plum, is quite different from the shy curculio beetle that laid the egg. (Fig. 95.)

227. How Insects Differ from Other Animals. Insects, like the frogs and snakes, are cold-blooded animals. The temperature of their bodies changes with that of the air or water, in whichever they happen to be. When cold weather comes, they find shelter under fallen leaves, sticks, stones, or may burrow into the ground and there remain quiet until warm weather returns. This way of passing the winter is called *hibernation*. While hibernating, they may be frozen stiff, or the eggs and larva may be frozen, but when the weather becomes favorable, many kinds will move about just as lively as ever. Severe freezing may kill some, but many will survive. Most animals have the bony skeleton inside of the body, but insects have the hard bony part on the outside. The muscles of insects are attached to the outer body wall and not to internal bones, as in other animals. Insects do not breathe through a mouth, but have little breathing pores along the sides of the body. The nerves of the insect that detect odors and guide it to its kind and food are usually in the little "feelers," or *antennæ*, or sometimes in the segments of the legs.

Some species of insects die soon after laying eggs, often before the eggs hatch; others may live on through the summer and produce several broods, as in the case of the cotton boll-weevil.

228. The Food of Insects. Insects are very peculiar about the food they eat. Just like the many species of parasitic fungi, each species feeds, usually, on just one kind of plant, or on closely related plants. In such cases we speak of the plant as the "host" for a particular

insect. The Colorado potato beetle (Fig. 96) is a native of the West, living on the western species of night-shades. When the Irish potato was introduced, it found a plant closely akin to its regular food plants, and on which it thrives to such an extent that it takes its name from the new host-plant. Sometimes there is a wide difference in the kinship of the host-plants. The feeding habits of the "boll-worm" of cotton, or the

Fig. 96. Colorado potato beetle. After Riley. *a*, eggs; *b*, larvæ; *c*, mature beetle.

"ear-worm" of corn, the same insect in both cases (Fig. 97), is a striking exception to the general rule, because it feeds on a number of different kinds of plants. When insects do not find acceptable host-plants, they die. Many insects are exclusively flesh-eating, such as the common "doodle-bugs," wasps, lady-bugs, and many species of wood ants. Red bugs and mosquitos are common forms of blood-sucking insects. Many para-sites are solely responsible for the spread of diseases.

The ticks, which are closely related to true insects, on cattle, are carriers of disease. Cattle do not have the splenic fever (sometimes called Texas fever) except when the germs are carried by ticks that bite them. The common bee lives on the nectar and pollen of flowers. It is not the only insect that lives on nectar. Most species of butterflies, moths, bumblebees, etc., are nectar-loving insects. We have already learned that these insects are very useful in bringing about the pollination of flowers.

229. The Feeding Habits of Different Stages. Many kinds of insects feed on plants cultivated by man. They attack the plants in various stages and ways. Most frequently it is the larval stage (caterpillar, grub, maggot) that destroys the plants by eating the leaves. The Colorado potato-bug lays its eggs on the leaves. The young larvæ are, therefore, hatched out-

Fig. 97. Corn ear-worm or cotton boll-worm. After Quaintance, Bureau of Entomology, United States Department of Agriculture.

right at the breakfast table. In some species of insects, the caterpillar stage occurs in great numbers, and they are, hence, often spoken of as "army worms," of which the "cotton army worm" is a common example in the South. Some caterpillars, known as cutworms, work only at night. When daylight comes, they are concealed under clods, and any trash that may be present. They are called "cutworms" because they have a habit of cut-

ting off young plants near the ground. They are the caterpillar stage of several kinds of night-flying moths. (Fig. 98.)
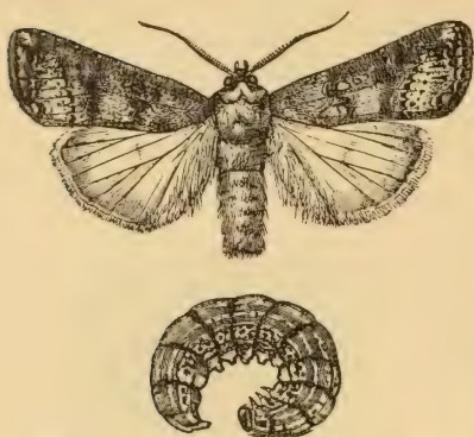
Fig. 98. Cutworm and moth. After Howard. Bureau of Entomology, United States, Department of Agriculture.

230. How Insects Get Their Food. (a) *By Living inside the Plant.* It quite often happens that the egg is deposited inside of some part of the plant and the larva develops there, as in the case of the larva of the plumgouger. As the larva is inside of the plant (Fig. 95), it cannot be destroyed by any of the sprays, and, in such cases, effort is made to catch and destroy the adults before the eggs are laid.

(b) *By Feeding on the Leaves.* Insects that feed directly on the leaves have mouth parts that are provided with scissors-like jaws by which their food is cut from the plant. To destroy insects that feed in this way, it is sufficient to cover the leaves with some suitable arsenic compound by sprays. When they eat the leaves, they consume enough of the poison to induce their death. Paris green, London purple, and white arsenic are the most usual poisons. Grasshoppers, locusts, and army worms are killed in this way. In some portions of Texas they have the leaf-cutting ants, which attack peach trees in great numbers and cut and carry off nearly all the leaves. These ants do not eat the leaves, but carry them into their underground nests and use

them as a soil on which to grow a fungus which they do eat. These ants are real "farmer insects," in that the food they eat is grown by their own efforts. Carbon bisulfide, poured into their nest, sometimes destroy the colony.

(c) *By Sucking the Juices.* We may distinguish another group of insects by the way they get their food from the plant or animal. Instead of having jaws with which they may bite off and chew their food, their mouth parts are shaped into a kind of tube which they
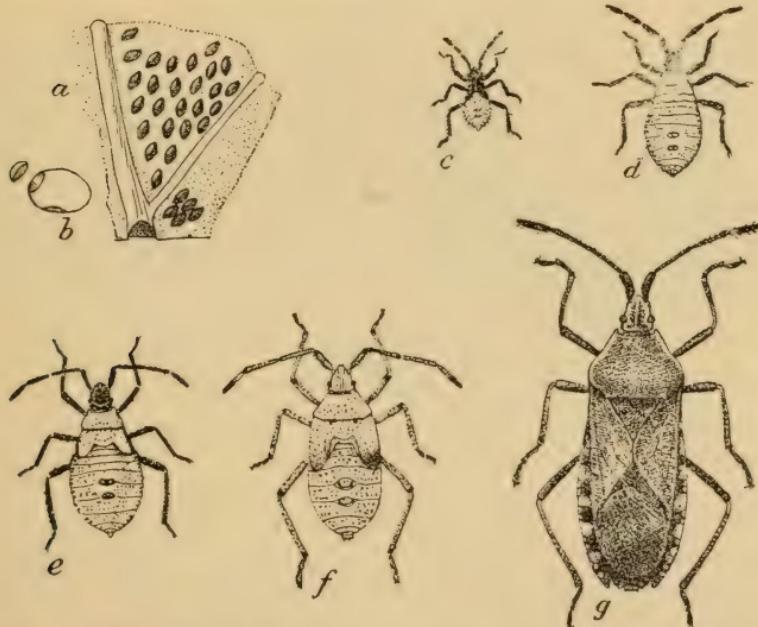
Fig. 99. Squash bug. *A*, eggs on leaf; *b*, egg-shell; *c, d, e, f*, nymphs; *g*, adult. After Chittenden. Bureau of Entomology, U. S. Department of Agriculture.

use to suck blood or sap. The squash-bug (Fig. 99), and the chinch-bug get their food by sucking. Plant lice, such as the green bug, and San José scale (Fig. 100) are also sucking insects.

230a. Structure of Insects. For this exercise the pupil should secure good specimens of the grasshopper and butterfly, as these two insects illustrate the difference of mouth parts as seen in insects. Some, as the grasshopper, have biting mouth parts, while others, as the butterfly, squash bug, etc., have mouth parts suited to pierce the plants and suck out their juices. (*a*) Note the large eyes in the front and side of the head of each insect. These are called compound eyes because they are made up of a great number of simple eyes. (*b*) Note also the feelers or antennæ, and the mouth parts. The large black jaws of the grasshopper are used for biting, while the long coiled tongue-like organ of the butterfly is used for obtaining food by sucking out the nectar from flowers.

Fig. 100.   San José scale on plum. *A*, natural size; *b*, magnified; *c*, greatly magnified.

230b. The next region of the body is called the thorax. In each insect the thorax is divided into three parts, each division has a pair of legs attached. All insects have six legs, and are sometimes called Hexapoda on this account. On each insect you will find two pairs of wings. These wings are attached to the second and third divisions of the thorax. Notice that the wing of the butterfly is covered with a "powder." This powder is made up of small scales attached to the wing in rows overlapping each other very much like the shingles of a roof. The wing of the grasshopper is smooth and firm with a large number of small lines running through it, called veins.

230c. The next division of the body is called the abdomen, which is made up of a number of segments or rings. By looking along the side of the abdomen of the grasshopper there will be seen a number of small openings or pores. These are the breathing pores

and nearly all insects have such breathing pores on the abdomen and thorax. At the tip of the abdomen the segments are changed a little in their form and size. This tip of the abdomen of the female is the egg depositor. The grasshoppers usually bore down into the ground and deposit their eggs, while other insects deposit their eggs in the bark of trees, young fruit, etc.

230d. All insects are constructed very much alike, there being slight differences in certain parts in the different kinds. Collect some of the common insects from the plants in the school-garden,

Fig. 101. This apple might have been kept sound by spraying.
From Cornell University Junior Naturalist.

or from the fields, and determine whether they have sucking or biting mouth parts.

231. General Method of Destroying Injurious Insects. The number of injurious insects appearing is affected by their food supply, weather conditions, and their natural insect enemies. Wherever it is possible, encouragement should be given to the natural enemies, some of which will soon be mentioned. Sometimes they can be killed by running heavy rollers over the fields, plowing or harrowing. The leaf-eating forms can frequently

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be killed by spraying the leaves with poisons. Others, like the sucking insects, may be killed by spraying directly onto the insect some substance that kills by contact, such as oils, alkali washes, etc. The poison must not be strong enough to injure the plants. In some cases, the insects may be killed by treating the plants with poisonous fumes or gases, such as tobacco smoke,

Fig. 102. Spraying.

and the deadly hydrocyanic acid gas, used especially for San José scale. Where plants are sprayed to prevent fungous diseases, the poison for insects may be applied in the same solution at the same time. There are many kinds of special machines for applying fungicides and insecticides. They are fully described in special books and bulletins.

232. Classification of Insecticides. Substances that are used to poison insects are called insecticides. There

are many substances used to kill insects. They may be grouped into three classes, according to the manner in which they poison the insect.

(a) *Food, or Internal Poisons*, are substances which poison by being taken into the digestive tract of the insect. This class includes various arsenical compounds, such as Paris green, London purple, lead arsenate. Poisons of this class are used for insects that chew their food, as the leaf-eating forms, unless the use of the poison render the plants dangerous for food, such as cabbage.

(b) *Contact Poison.* Substances that destroy by attacking the body of the insect, such as washes of caustic alkalies, oils, etc. They are used for sucking insects, i. e., those having beaks, such as the San José scale.

(c) *Tracheal Poisons.* Substances which enter the breathing pores of the insect and cause death by poisoning or suffocation. Smoke, and the deadly hydrocyanic acid gas, Pyrethrum, or "insect powder," and carbon bisulphide, belong to this class.
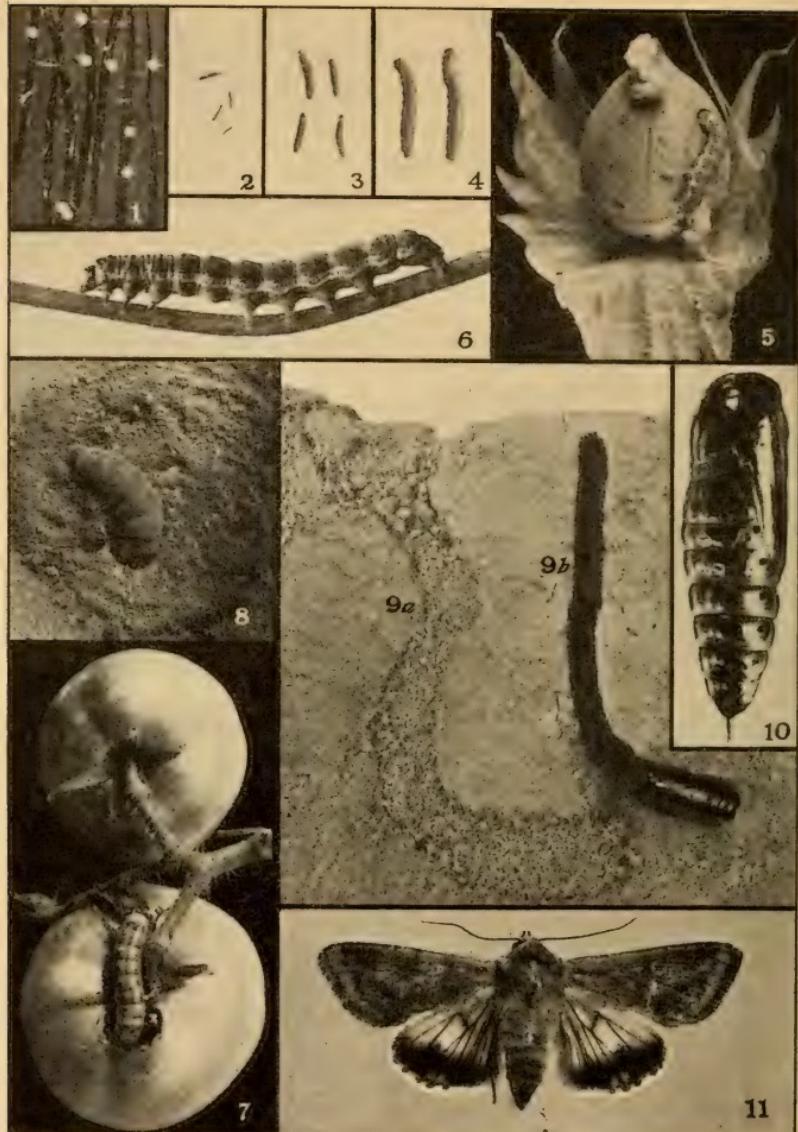
Fig. 103. The cotton-boll worm. After Quaintance and Brues. 1, Eggs on corn silk, twice natural size; 2-4, early larval stages, somewhat enlarged; 5, boll-worm eating into half-grown ball, natural size; 6, mature larva, natural size; 7, boll-worm on green tomato, one-half natural size; 8, full grown larva burrowing into soil for pupation; 9a, showing line of movement of larva into the soil; 9b, pupal chamber with pupa at bottom; 10, mature pupa, slightly magnified; 11, boll-worm moth with wings expanded, natural size.

CHAPTER XXIII

SOME SPECIAL INJURIOUS INSECTS

233. Insects that Attack Cotton. There are several species of insects that injure the cotton plant, such as the cotton army or leaf-worm, cotton boll-worm, the Mexican boll-weevil, and the cotton aphis. The leaf-worm and boll-worm may be destroyed by spraying or dusting with arsenical poisons.

234. The Boll-Worm of cotton, damages cotton by destroying the locks of the bolls. The same insect damages the tips of more than 75 per cent of the ears in the corn fields. The damage to corn ears is probably fully 3 to 5 per cent of the crop. The pupæ hibernate in the ground through the fall and winter and do not mature into moths until late in the spring. These facts suggest the advisability of early fall plowing to expose the pupa to the severe weather conditions of the winter seasons, predacious insects and birds. (What other reasons have already been mentioned for early plowing?) Advantage is taken of the habit of the insect of attacking corn and cowpeas in preference to cotton, to protect the latter. "Trap rows" of corn and cowpeas are planted near the cotton to attract the moths. In this way the damage to the cotton is lessened. Corn is used, also, in pro-
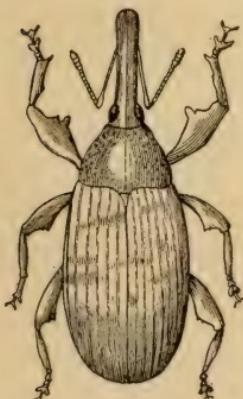
Fig. 104. Mexican Cotton-boll weevil. (Enlarged five times.) Howard, United States Department of Agriculture.

tecting tomatoes from this insect. Much better results
will be secured if the corn is planted late. (Fig. 103).

235. The Mexican Boll-Weevil is a true weevil,
resembling very closely the plum curculio. It has been
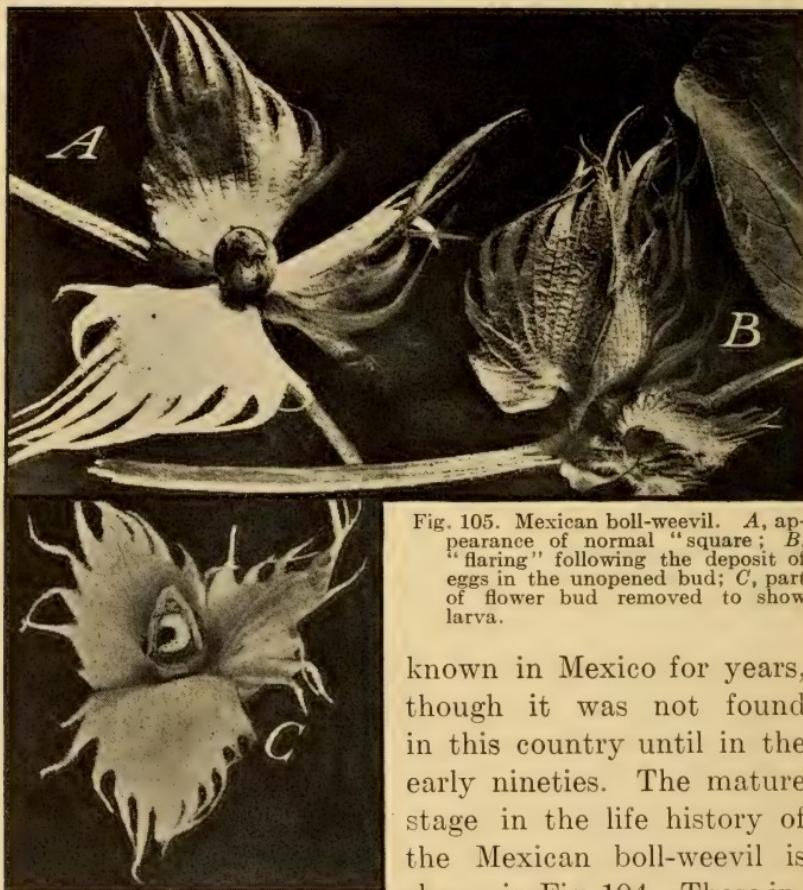
Fig. 105. Mexican boll-weevil. *A*, ap-
pearance of normal "square; *B*,
"flaring" following the deposit of
eggs in the unopened bud; *C*, part
of flower bud removed to show
larva.

known in Mexico for years,
though it was not found
in this country until in the
early nineties. The mature
stage in the life history of
the Mexican boll-weevil is
shown in Fig. 104. These in-
sects leave their winter shelter early in the spring and
deposit the eggs in the flower-buds or squares. The
weevil does not deposit eggs in the young bolls when
the flower-buds are to be found. When the egg is thrust

into the flower-bud ("stung," as it is sometimes improperly called), the square or calyx is soon "flared," as shown in Fig. 105, and then drops to the ground. In about twenty-five or thirty days from the laying of the egg, the mature weevils emerge from the fallen flower-buds and start a new generation. Each female weevil, starting early in the season, may, if conditions are favorable, produce enough to destroy a crop of cotton. The adult weevils hibernate in winter in the many unopened damaged bolls or under any kind of trash that may be available, especially in the leaves of nearby woods. During the following spring, they begin to emerge in considerable numbers after the first few weeks of warm weather. They feed on the tender portions of the young cotton. The eggs are deposited in the first

Fig. 106. Late-fall boll, showing how beetles hide between boll and involucre.

young flower-buds. In 1904, it was estimated that the loss to Texas cotton-growers was equal to 450,000 bales, but, by using improved varieties of cotton, early planting, distance between rows, and other measures, a fair yield of cotton is now secured. More than thirty species of birds are known to use the boll-weevil as food. Ants, ichneumon flies, wasps and other agencies assist man in his fight to keep this pest under control.

236. The Spread of the Boll-Weevil. Fig. 107 shows the advances of this great pest since it was first dis-

Fig. 107. Illustrating the spread of the Mexican cotton-boll weevil. From data furnished by Bureau of Entomology, United States Department of Agriculture.

covered in the United States. Birds, snakes and predaceous insects assist man in holding the boll-weevil under control, but no fact has yet been discovered that suggests that it will not spread over the entire cotton-growing section.

237. Tent Caterpillars are often found in fruit trees. They are easily discovered in the spring by their large webs supported on the branches. They may be found much earlier as small bunches of eggs, like those shown in Fig. 108*c*. They are laid late in the summer and covered by a sticky substance to protect them from the winter rains. They hatch out usually just about the time the buds open and the caterpillars feed on the young buds and leaves. They soon spin a delicate cloth-like web or tent, to which they retire at night, and in bad weather. These caterpillars are well marked with dots and lines along the bodies that are characteristic for each species. After a time
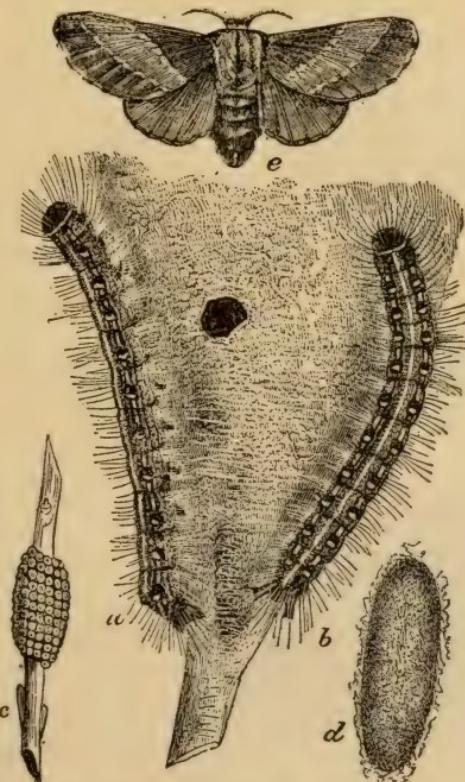
Fig. 108. The tent-caterpillar. *a* and *b*, larvæ; *c*, egg-cluster; *d*, cocoon; *e*, full-grown.

they leave the tree and each individual spins a paper-like case, called a "cocoon," in some sheltered place. The adult moth emerges from the cocoon in a few weeks, and lays the eggs as mentioned above. These changes may be observed by bringing the almost mature caterpillars into wire-screened cages. These caterpillars are attacked by many parasites, birds, snakes, frogs, and particularly by birds. The orchard should be inspected in the early spring for webs.

238. "Wire-worms" are very common in fields. They are the larval stage of various species of night-flying beetles, such as the click-beetles. The adult lives on the nectar obtained from flowers while the larval stage lives in the ground and thrives on the roots, leaves, and stems of young plants.

Fig. 109. A corn-plant growing in a root-cage infested by wire-worms and click-beetles (from a specimen in the Cornell Insectary).

239. Plant-lice, or Aphids, are common everywhere. There are many kinds, and all are quite small. Plant-lice are soft-bodied, usually green, like the "green bug," but sometimes colored red or black according to the plant they are infesting. Most of them are wingless, though some of them will have two pairs of transparent wings. They almost always occur in colonies,

frequently of immense numbers. They feed upon the leaves, buds, tender stems, and even the roots in some sorts of plants. They do much damage by sucking the plant juices. Some species secrete a substance known as "honey dew," which is sought after by ants. The ants care for the aphis and protect them from the depredations of predaceous insects. The scale insects are classed with the plant-lice. The San José scale is the most serious representative.

Fig. 110. The spring-grain aphis. *a*, wingless female; *b*, larva; *c*, pupa; *d*, winged migrant. After Webster, United States Department of Agriculture.

239a. Colonies of plant-lice may be found frequently on roadside weeds, sometimes under the folded edges of leaves tended by ants. Such a colony should be closely observed. Small tubes may be seen on the abdomen of the lice covered with drops of honey dew. The ants have a way of stroking the lice to make them give up the honey dew. This action is often fancifully called "ants milking their cows."

240. Insects Injurious to Stored Grain. The insects that damage stored grain are the larvæ of moths and beetles, and several species of weevils closely akin to the plum-gouger and cotton boll-weevil. Corn, wheat, peas, and many other seeds are often damaged by these insects while stored. Some species are very destructive. The "rice-weevil" is the most destructive, particularly to corn, peas, barley, kafir corn, etc. The two most common species of weevil are shown in Fig. 111. The

the rice-weevil is the larger, and has a dull brown color. The eggs are laid in the corn, often before it is gathered. During warm weather it requires about six weeks to mature a weevil from the egg, while, in cold weather, they multiply very slowly. The egg-laying continues over a considerable period and, as it requires such a short while to mature a new brood, it is no wonder that they are found in such numbers in grain stored for any considerable time. It is estimated that, in the course of a season, they mature six or
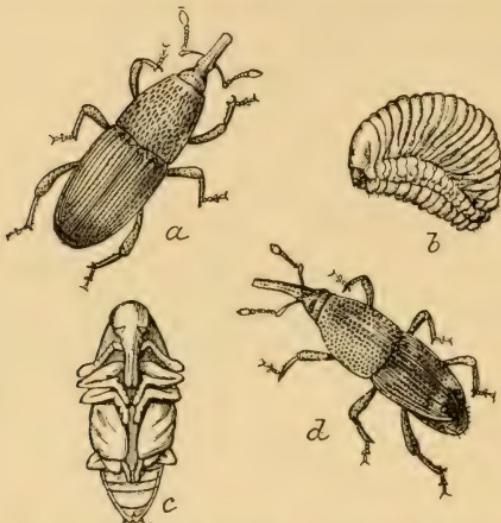
Fig. 111. Granary weevil. *a*, adult; *b*, larva; *c*, pupa; *d*, rice weevil. All enlarged. After Chittenden.

more generations, amounting to 500 or more individuals from a single pair.

241. The Grain Moths do more damage to the stored grain than the weevils. The most common species is the Angoumois grain moth, so named from a province of Angoumois, France. It attacks grain in the field as well as in the bin. The adult somewhat resembles the common clothes moth. It is light grayish brown and about a half-inch across when the wings are expanded. The eggs are deposited in clusters of twenty to thirty and require only about four to seven, or more, days to hatch the caterpillars. The latter bore into the

grain, and, after feeding on the starchy matter for about three weeks, form a thin silken cocoon, from which it emerges a few days later. About thirty-five days are used in passing from egg to adult. Four to, possibly, eight broods are formed during the year. When grain is stored in bulk, only the surface layers are infested. Both the weevils and moths are subject to attacks by parasites.

242. Preventing Injury to Stored Grain. To reduce the injury to stored grain, use is made of repellants like napthelene (so-called "moth balls"), salt, air-slaked lime, and other substances which, while not poisonous, drive the insect out. A temperature of 125° Fahr. is sufficient to kill weevils, though more than 150° Fahr. may be endured by dry grain without loss of germinating power. Treating the grains to the vapors of bisulfide of carbon in tight bins is by far the most satisfactory means of protecting stored grain. In destroying the insects, use one pound to one hundred bushels of grain.
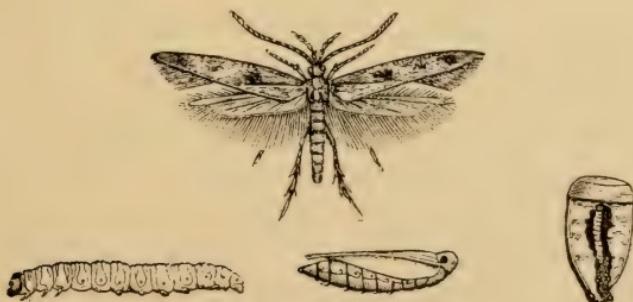
Fig. 112.   Grain moth

USEFUL INSECTS

243. Useful Insects. Some insects are useful because they supply food, as the honey-bee. Others supply materials for clothing, as the silkworm. Still others, as we have seen, cause flowers to set fruit by carrying pollen from flower to flower. (See ¶ 140.) There are many species which are especially useful in man's battle with the forces of nature, because they prey upon the injurious insects.

244. Wasps. There are many kinds of wasps. The common "red wasps" and yellow jackets,"" with their paper nests made out of the fragments of plants, are well known. The mud-dauber is another common wasp, There are many species of wasps that do not live in colonies like the ones just mentioned, but live singly. and are, hence, called "solitary wasps." The wasps are quite closely related to the domestic bees, and bumble-bees, but instead of gathering nectar and pollen for food, as the bees do, they feed on other insects. The mud-dauber fills the mud-cells with the bodies of young spiders, flies, etc., and before sealing up the hole, deposits an egg. The food for the larva is there ready for it when it is hatched. Wasps are said to catch the biting flies that worry stock, and, especially, the larvæ of the boll-weevil. Wasps' nests should not be destroyed except, possibly, in orchards.

245. Ichneumon Flies, of which there are many kinds, are closely related to the bees and wasps. The

adult often feeds on nectar. The usefulness of this class of insects is due to the fact that the young are parasites. They do not secure their prey by force. Instead of catching the insects and carrying them to the young larvæ, their eggs are deposited in the bodies of their victims, and there grow into grubs. The grubs either mature in the body of the hosts, or come out and mature in the ground. The eggs are most often deposited in caterpillars, though sometimes in the chrysalis and
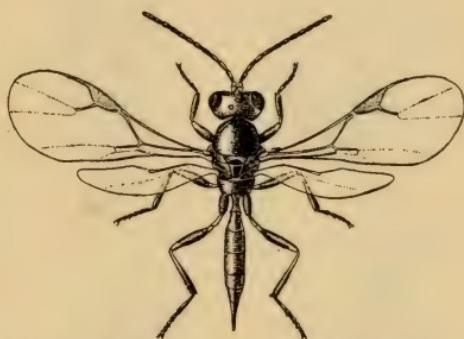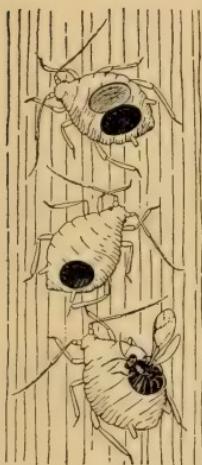
Fig. 113. *A*, dead "green bug," showing hole from which the matured parasite emerges. The top figure shows the lid still attached, but pushed back; the bottom figure shows the parasite emerging; *B*, principal parasite of the spring grain-aphis or "green-bug;" adult female, highly magnified. After Webster, United States Department of Agriculture.

on the adult stage, or even in the eggs. We find here the same specialization in hosts that we noticed in the fungi, and plant-eating insects. Each species of parasitic fly rarely attacks more than one species of insect. Two species (Fig. 113), of the ichneumon fly attack the green bug. They thrive only during the warm weather of spring, however, while the green bugs may endure much cold weather. Below central Texas, the parasitic flies are active at all seasons and that section has never

been seriously damaged by the green bug. In other parts, the entire grain crops have been almost destroyed several times because the cool weather retarded the multiplication of the parasites.

Ichneumon flies are parasitized by other ichneumon flies, and these in turn by others, reminding one of the old adage that "Large fleas have smaller fleas to bite 'em."
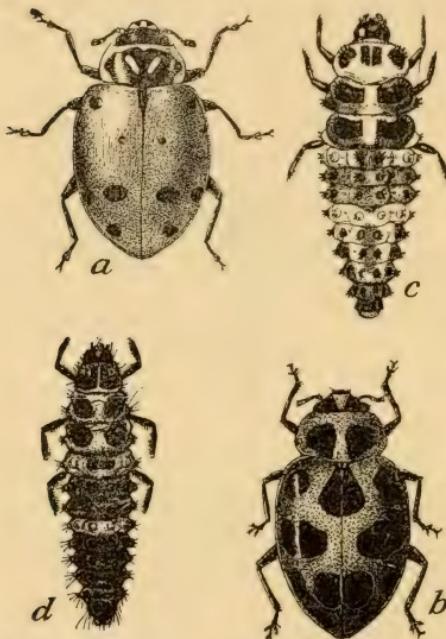
Fig. 114. Two common species of lady bugs. *a*, hippodamia; *b*, megilla; *c* and *d*, larva stages. After Chittenden, United States Department of Agriculture.

246. Ants. Many species of ants live on the eggs and larvæ of other insects. They are very useful in cotton fields because they destroy many boll-weevils. The common red stinging ant lives on weed seeds and wild grain.

247. Lady Bugs are another class of insect-eating insects. They feed on eggs of the Colorado potato bugs, chinch bugs, and plant-lice. They are easily recognized by their red and black-spotted color. There are two kinds of lady bugs found in the Southwest. One species, *Megilla maculata* (Fig. 114), is especially active in feeding on the green bug on grains, while another, *Hippodamia convergens*, is more active on the plant-lice on cotton and melons. The latter will lay about fifteen eggs per

day, and often a total of 500 eggs. These are deposited on leaves in clusters of from a few to fifty in a place. A lady bug will eat about fifty aphis per day. We recognize these insects as a benefit to mankind in various ways.

248. Parasitic Insects are possibly the most important class of beneficial insects. Without them, the locusts and grasshoppers, the caterpillars of butterflies and moths, and many other kinds would destroy all the plants. Every farm should have a "lady bug patch." Unless these insects have food during the winter months, they die. They require plenty of insect food, and this should be provided by growing some crop that harbors insects through the winter. Some winter-growing plant, like rape which has a winter insect parasite, the cabbage aphis. The lady bugs, thus having food through the winter, grow and multiply until spring when food naturally becomes abundant.

CHAPTER XXV

WILD BIRDS AND OTHER INSECT-EATING ANIMALS

249. Most Birds Benefit the Farmer, because their food consists very largely of harmful insects, weed seeds, mice, etc. Some birds eat the grain or do much damage to the fruit, but without the birds, the insects would be far more destructive. In 1753, Benjamin Franklin wrote to a friend:—"In New England they once thought blackbirds useless, and mischievous to the corn. They made efforts to destroy them. The consequence was, the blackbirds diminished, but a kind of worm which devoured their grass, and which the blackbirds used to feed upon, increased prodigiously; then, finding their loss in grass greater than their gain in corn, they wished again for the blackbirds."

250. Birds Like Insect Food Best. Every one has noticed how the field-larks, and other birds fly into the

Fig. 115. Food of the meadow-lark by months.

newly plowed furrow. They are not looking for freshly planted seeds as some suppose, but for worms and insects which the plow uncovers. They prefer insects, but will eat weed or grain seeds if insects are scarce. In summer the field-lark (or "meadow-lark," as he is most often called in the North) eats insects

(178)

almost entirely, but in winter when he cannot find insects, he has to eat weed seeds, and waste grain. (See Fig. 115 and table of food by months.) The young of all kind of birds, including those of the vegetable-feeding adults, feed largely on insects. (See Fig. 116.)

FOOD FOR THE YEAR.

Months	Stomachs Examined	Animal Food Per cent	Grain Per cent	Weed Seeds Per cent	Total Per cent
January	13	24.36	75.28	.36	100
February	1	.00	25.00	75.00	100
March..........	12	73.14	17.00	9.86	100
April...........	28	77.51	15.10	7.39	100
May	8	97.99	1.88	.13	100
June	20	95.79	2.10	2.11	100
July	18	97.32	.00	2.68	100
August	28	99.35	.00	.65	100
September	29	99.20	.40	.40	100
October.........	40	94.39	.61	5.00	100
November	22	77.08	6.50	16.42	100
December.......	19	39.22	32.70	28.08	100
Total for year....	238	72.95	14.71	12.34	100

251. Beneficial Birds Should not be Killed for food, neither for sport, nor for decorations for hats. Every
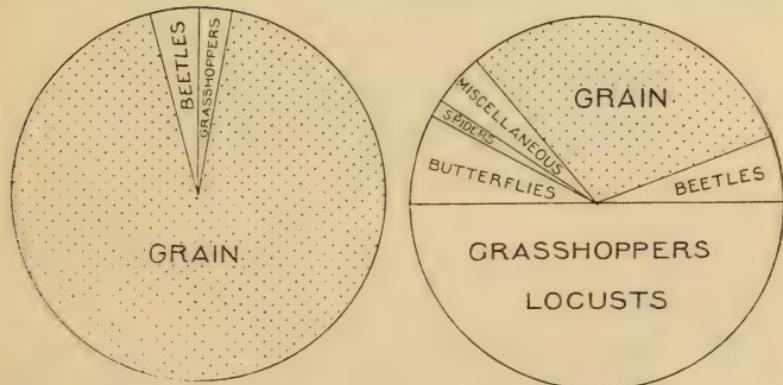
Fig. 116. Diagram showing proportions of food of English sparrow (*Passer domesticus*), young and adult.

time one feels tempted to kill birds, he should not only think of the good they do by destroying insects and weed seeds, but possibly not far off there is a group of tender nestlings waiting for mama or papa bird to come home with a morsel of food, to check the pangs of hunger. When women decorate their hats with aigrettes, they encourage selfish persons to kill harmless birds. It is against the laws of many states to kill the useful birds. No one should want to destroy them. Birds should be protected at all seasons. Define "game birds." "Non-game birds," as used in the laws of your state.

252. English Sparrows (Fig. 117) live almost exclusively on the farmers' crops, besides destroying the
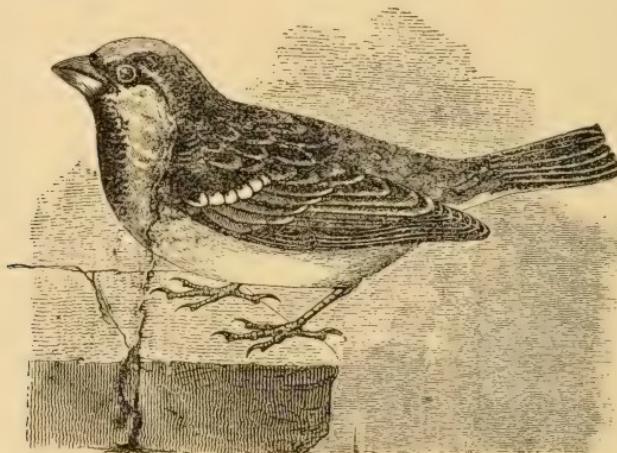
Fig. 117. English sparrow.

eggs and nests of other birds. They should be destroyed. The native species of sparrows are insect-eating birds.

253. Migration of Birds. Some birds live all the time in the same locality, like the partridge, Texas road-runner, and downy woodpecker, the sparrow, and the

cardinal, while other kinds, as the robin, bluejay, etc., spend one season in one part of the world, and the others elsewhere. Everybody knows that the wild geese "fly over" in the fall, going south to the warm salt waters, and back again in the spring on their way to the breeding-grounds in Canada. Likewise, the field-lark spends the summer in the North, and in the fall and winter he makes his home in the South. (Fig. 118.)

Fig. 118. Meadow lark or field lark.
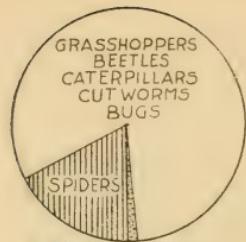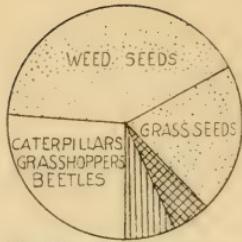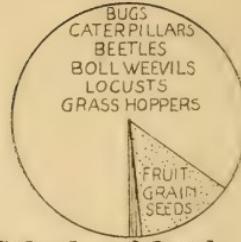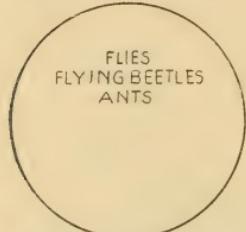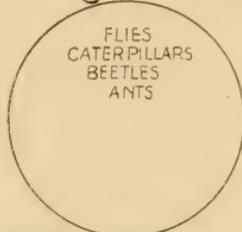
253a. Make a list of the kinds of birds, found in the county. How many kinds are permanent residents, and how many visit for only a part of the year?

254. The Feeding Habits of Birds. The farmer is interested in the birds because they eat the insects that destroy his crops. The illustrations, Figs. 119 and 120 show how much of each kind of food some common birds eat. Some birds, like the swallows, and scissor-tailed flycatcher, live on insects almost entirely. Others, like the dove, eat nearly all weed seeds and grain, but most birds eat some of both. It will be interesting to
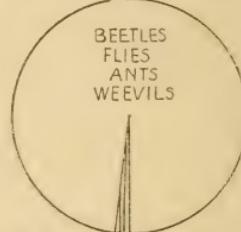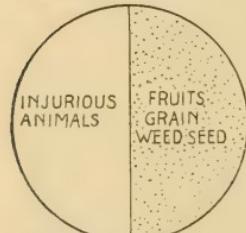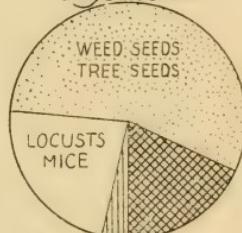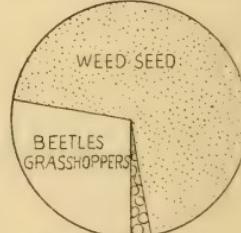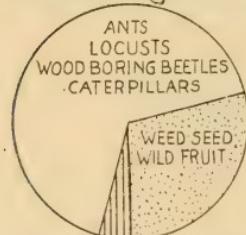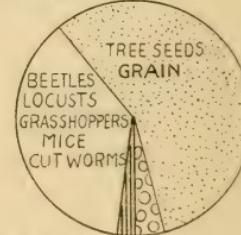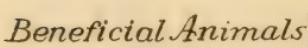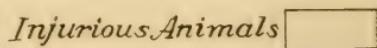
Fig. 119. Diagram illustrating the proportions of the food of various beneficial and destructive birds.
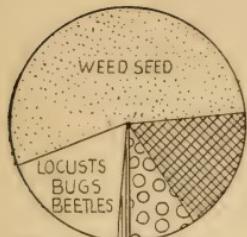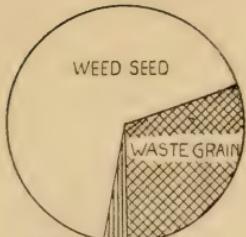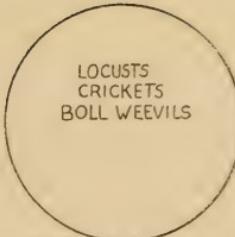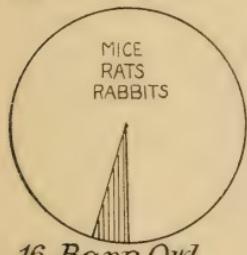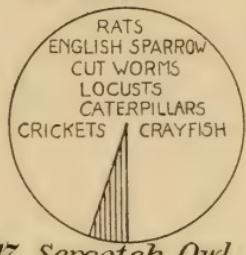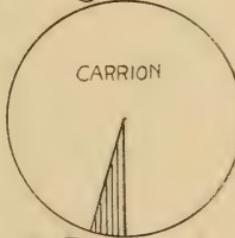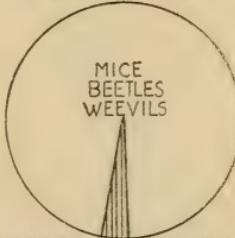
Fig. 120. Diagram illustrating the proportions of the food of various beneficial and destructive birds.

watch the many kinds of birds in your neighborhood, and see how they catch their food. The scissor-tails capture the insects that fly during the day. At night the whippoorwills and night-hawks begin to fly, and catch the insects that the day-flying birds miss. Some kinds of birds, like the wren and vireos, go carefully from leaf to leaf, looking for the small, half-hidden insects on the under sides. Still, again, the busy woodpecker goes over the bark looking for insect eggs and larvæ, or boring for ants and wood-worms. Other birds, like the larks and sparrows, scan the ground for creeping insects, while still others, with long legs and bills, go to the bottom of the pool for the little swimmers that are seemingly safe from molestation.

254a. If a bird eats on an average one hundred insects a day, and there are three birds to every acre of land, how many insects will they eat in a year? How many insects would they take from the largest orchard in the neighborhood?

254b. A quail was found to have 10,000 weed and grass seeds in the craw when killed. If each quail in a covey of fifteen should destroy this many weed seeds daily for a year, how many weeds would be destroyed?

255. Change of Feeding Habits in Migration. Some birds that spend a part of a season in one part of the country, and the other in a distant section, change their feeding habits. A good illustration is the bobolink, or rice bird. It breeds in the North, and feeds largely on insects, and but slightly on grain. In the South it is called "rice bird" because it prefers the rice field, where 50 to 80 per cent of its food is rice.

256. Bird-houses. Instead of shooting at birds, and throwing stones to scare them, we should encourage the useful birds to build their nests around the barns and in the orchards. Many persons build houses to

CARDINAL
Upper Figure, Female; Lower Figure, Male.
(One-half natural size.)

attract martins and sparrows. A simple house may be made with old tin cans, as shown in Fig. 121, using a board for a roof, and allowing part of the top of the can
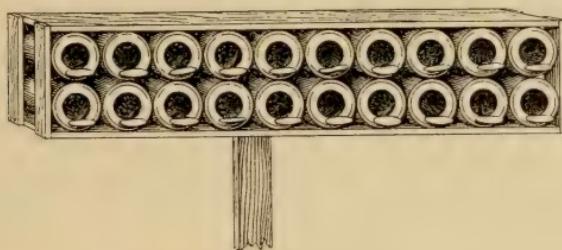

Fig. 121. A good way to use tin cans.

to remain, to make a lighting place. A good house for martins is shown in Fig. 122.

257. Other Animals that Destroy Insects. "Horned frogs" (though they are really horned lizards) and common frogs live on insects, as, also, do most snakes. Even the old chicken snakes make way with many times more rats and mice than they do with young chickens.
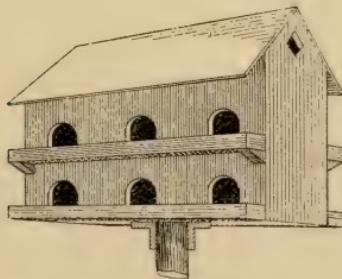
Fig. 122. A simple Martin house.
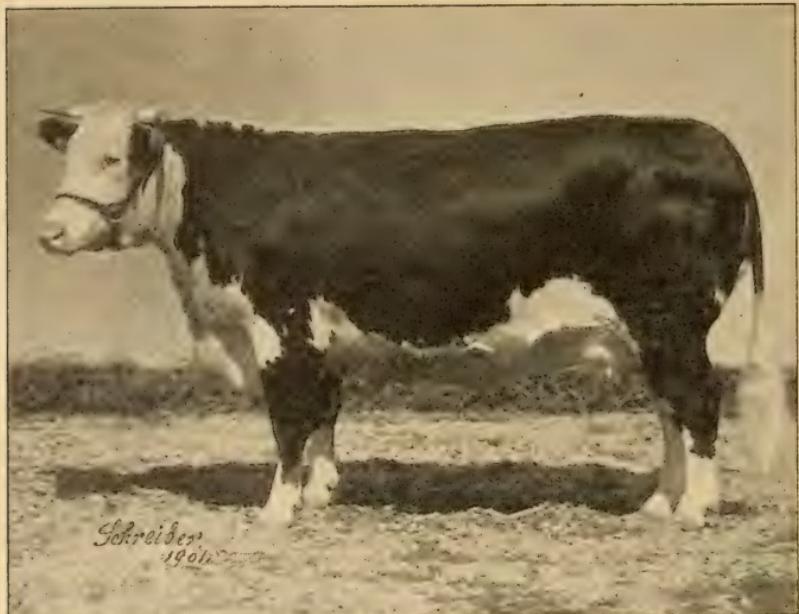
Fig. 123. Side, front and rear view of Hereford cow, "Lady Briton 16," owned by Comstock & Son, Albany, Mo.

CHAPTER XXVI

ANIMAL HUSBANDRY

258. Utilizing Farm Crops. The farmer grows grass, alfalfa, grains, cotton, fruits and other crops which he desires to convert into money. There are two ways of marketing the surplus feeds grown on the farm: (1) The crops may be sold to other persons to be fed to stock, or (2) they may be fed to animals on the farm where they are produced and worked up into a variety of products of less weight and bulk, as beef, pork, poultry, eggs, milk, horses, mules, cows, etc. These finished products may often be marketed for much more than could be secured for the feed alone. And, in addition, there will be retained on the farm much of the fertility, in the feeds for the benefit of succeeding crops.

259. The Farm is a Factory where the plant and animal products are made from the crude substances of the air and soil. It is just as necessary to keep the soil able to sustain large yields as to keep the machinery in the mills in good working order. The wealth-producing power of the farm lies in the productiveness of the soils. It costs something every year to restore to the soil the power to make a large yield of wheat (see ¶111), but it costs more to grow wheat on land that averages only half crops during the life of a farmer.

260. The Cost of Manufacture and the value of the

feeds should be counted against the value of the products. The value of a product is determined by its kind, the supply offered at a given time, and the demand.

261. Animal Husbandry is the natural companion of crop farming. When the products of the fields and meadows are removed from the farm each year, there is a continual loss of fertility, which leads to certain poverty of the farm and farmer. When these are fed to the stock on the farm much of the fertility in the crops may be returned to the land.

262. Stock Farming varies and distributes the farmer's labor. It gives him opportunity to work every day in the year by which he may earn something for his family. An all-grain crop or hay crop, or cotton crop, etc., overtaxes the farm labor in one season and leaves it in comparative idleness the next. Stock farming encourages system in rotation of crops, and thus tends to maintain the land in a high state of productiveness.

263. In Selecting Animals for the Farm, the farmer should use just as good judgment as the manufacturer does in buying machinery, for the stock is the machinery that makes the crude products of the farm into salable products. The machines used in manufacturing have been greatly improved to cheapen production in special lines. What shall be the character of the machines which the farmer uses to convert his feeds into finished products? Shall it be the latest improved,—by years of breeding and selecting, to secure a breed that will give a larger return of meat, butter, eggs, wool, etc., for each pound of feed supplied?

264. Many Animals Are Unsuited for the purpose for which they are kept. The Illinois Agricultural Experiment Station made individual records for a full

DAILY MILK AND FEED RECORD FOR MONTH

Owner of Herd: *J. G. Smith* : Post Office, *Birr...*

NAME:	Lilly	Spot	Daisy	Cherry	Brindle
BREED:	Jersey	Holstein	Grade Jersey	Grade Durham	native Cross
Date of feed record,¹	5 15 25	5 15 25	5 15 25	5 15 25	5 15 25
Cow Pea Hay:	10 10 10	12 12 12	8 10 8	10 12 10	10 10 10
Silage or soiling crop:	25 25 25	35 35 35	30 30 30	35 35 35	35 35 35
Grain: Cotton Seed Meal	2½ 2½ 2½	3 3 3	3 3 3	3 3 3	3 3 3

8–57.

DATE.	A.M. P.M.	A.M. P.M.	A.M. P.M.	A.M. P.M.	A.M. P.M.
1	13½ 11	16 13	10 11	10 8	3 3
2	12 11	15 13	10 9	9 8	4 3
3	14 12	16 14	11 10	9 9	4 2
4	14 13	17 15	11 11	10 10	4 3
5	14½ 14	17 16	12 10	10 10	3 3
6	14 14	17 15	12 11	11 10	3 2
7	15 14	17 16	12 12	11 10	3 3
8	15 12	17 15	12 11	10 10	3 2
Cold Rain 9	14 11	15 13	12 10	10 9	2 2
Cold Weather 10	14 12	15 12	12 10	10 9	2 2
" " 11	14 13	15 14	12 11	8 8	2 2
12	15 14	17 15	13 11	9 8	3 2
30	15 13	15 15	11 10	10 9	3 2
31	15 15	16 15	10 9	10 8	3 2
TOTAL,	441 401	586 461	353 324	305 274	91 78
Total for month,	842	967	674	579	166
Butterfat, per cent,	6 %	3½ %	5 %	4 %	3.8
Butterfat, lbs.,	50.52	33.84	33.70	23.16	6.3
Butter or cream, lbs.,					
Price per gal ... cts. lb. 22 cts.	25¢	25¢	25¢	25¢	25¢
Value,	$12.63	$8.46	$8.42½	$5.79	$1.57
Value skim milk,	1.79	2.16	1.48	1.30	.37
Total value,	14.42	10.62	9.90½	7.09	1.94
Cost,	2.69	4.55	3.72	4.32	4.42
Profit,	$11.73	$6.04	$6.18½	$2.77	-2.48

¹ D. 185—12-16-07—5,000. ⁴ Cost of pasture per head, ...

Fig. 124. Record of five cows for one month. Is the profit above cost of feed sufficient to pay for care? Record furnished by Prof. C. O. Moser.

year of the butter produced by 554 cows in Illinois
dairies. The average for the 139 poorest was 133.5
pounds of butter-fat and for the 139 best, 301 pounds,
or an average difference of 167.5 pounds butter-fat per
year. At 25 cents per pound this is $41.87 per cow.

264a. Figure the gross and net returns per year to the dairy-
man for labor and interest on the investment for each of the above
groups of cows. Allow $30 per year for the cost of feed for each
cow, and 25 cents per pound for butter-fat. The cows were valued
at $50 each. Were they all worth this much?

265. Records of Individual Performance should be
made of cows, hens, etc., to determine the cost of keep-
ing and the returns of the farmer. By this means the
profitable animals may be recognized, as also the unprofi-
table ones. The latter should be discarded. The farmer
may, by attention to these matters, learn that some
animals are being fed at a loss.

265a. Milk and Butter Records. Secure records of the amount
of milk, and amount of butter, from cows in the neighborhood for
a single week. Calculate the value of the product at current prices.
Count the amount and cost of the feed consumed. Determine the
returns for labor, etc. (See Fig. 124 and ¶352.)

265b. Growth of Pigs. Weigh a weaned pig once a week for
four weeks, and calculate the daily gain in weight. Allow for cost
of feed and calculate the cost per pound gain. Market prices may
be secured from the daily papers.

265c. Record of Loretta D. (see Fig. 131), the champion "best
cow of any breed" for economical butter-production in the dairy
test at the St. Louis Exposition in a 120-day test, average daily flow
of milk was 48.35 pounds, containing 2.33 pounds of actual butter-
fat (equal to 2.75 pounds of standard quality butter). The cost of
her feed was twenty-five cents per day. Calculate the value of the
milk and butter for ten months.

265d. Record of Colantha 4th's Johanna, (see Fig. 125), in a
year test completed December 24, 1907, was 27,432 pounds milk,
yielding 998 pounds of butter-fat. This is the world's record, both

for milk and butter, for any cow of any breed. What would be the value of her milk and butter at current prices?

266. What Constitutes a Breed? Breed, as applied to live-stock, corresponds to *variety* in cultivated plants. The various breeds of poultry, cattle, horses, sheep, etc., descended from a common stock. The differences which
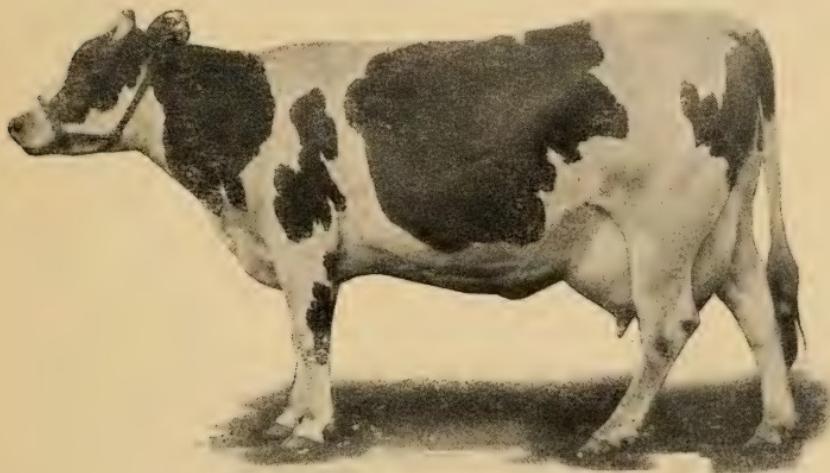

Fig. 125. Colantha 4th's Johanna.

RECORD OF COLANTHA 4TH'S JOHANNA.

Days	Time	Milk	Butter-fat		Estimated butter
		Lbs.	Per cent	Total	
1	Feb. 6, 1907	100.8	3.96	3.99	4.65
7	Feb. 6 to 12..........	651.7	4.37	28.17	32.86
30	Jan. 21 to Feb. 20	2,873.6	3.86	110.83	129.30
60	Dec. 27 to Feb. 25....	5,326.7	3.91	208.39	243.12
365	Dec. 24, '06 to Dec., '07	27,432.5	....	998.25	1,165.00

we recognize in the breeds are the result of continued selections.

267. Origin of Breeds. Man long ago recognized differences in the ability of individual animals to convert their food into milk, wool, feathers, eggs, etc. Therefore we select animals, not so much for their ability to endure hardships, but for their power to produce something in response to care. Continued selection has produced breeds of animals having certain characters strongly developed. They are called "special-purpose breeds."

CHAPTER XXVII

TYPES AND BREEDS OF CATTLE

268. The Beef Types are distinguished by their ability to lay on large amounts of flesh. Their bodies have a rounded form, with strong back and well-sprung ribs. They have full quarters, straight bottom and top
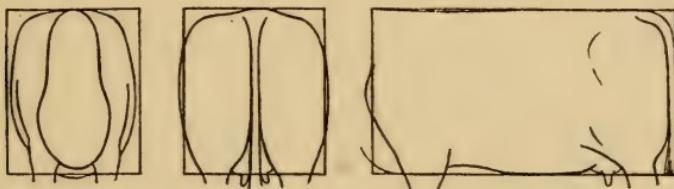
Fig. 126. Outlines of shape of beef cow as compared with parallelograms.

lines (see Fig. 127), and a tendency to develop flesh at an early age. Careful breeders prefer the animal that locates a large amount of its flesh where it is worth most, i. e., in regions supplying the valuable cuts of steak. (See Fig. 128.) Animals having these qualities so fixed by repeated selections that they regularly appear in the offspring, belong to the beef-breeds.

269. The Shorthorn, like the Herefords, is an old English breed. The shorthorns adhere closely to the
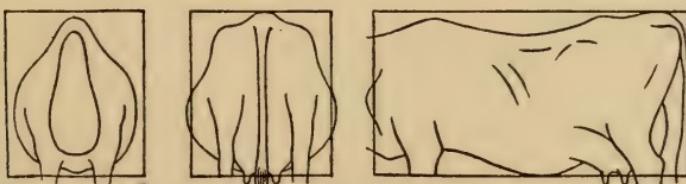
Fig. 127. Outlines of shape of dairy cow as compared with parallelograms.

(193)

beef type, but many strains are good milkers, and are classed as "general purpose" animals. They are of very

Fig. 128. Chicago retail dealers' method of cutting beef

large size, the cows often ranging from 1,400 to 2,000 pounds. The horn is short, the hindquarters are broad and well filled. A considerable range of color is allowed in the shorthorns—from light to dark red, or roan, the latter formed by a mixture of red and white hairs. The Polled Durhams are an offshoot of the Shorthorns. (Fig. 129.) The Shorthorn is one of the most popular of beef breeds. During the course of its development three

Fig. 129. A prize-winning Polled Durham. Ruby of Buttonwood

types have come to be recognized—the Bates, Booth, and Crookshanks, or Scotch Shorthorns. The former two are English in origin and differ from each other in the following characters: The Bates cattle have been bred for beauty and symmetry, style and milking qualities, while the Booth strain constitution, wide thick-fleshed backs and length of quarters have been empha-
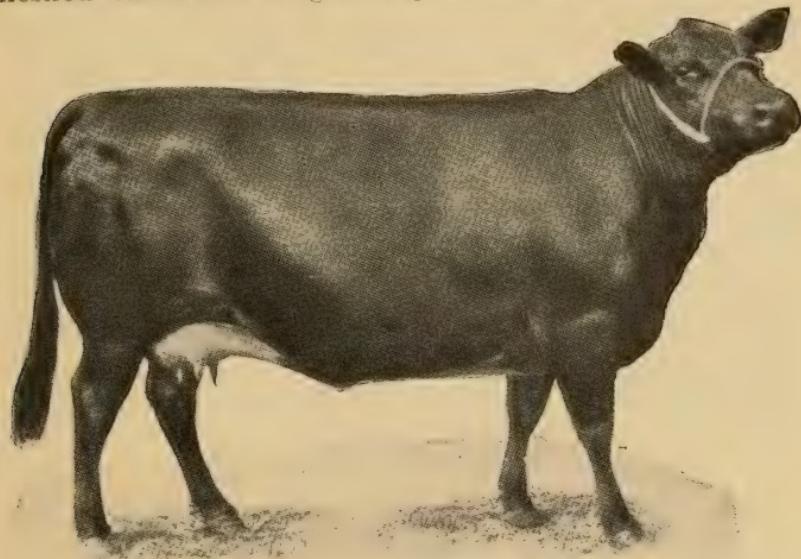
Fig. 130. A typical Aberdeen Angus.

sized. The Crookshanks, or Scotch strain, are low, have block forms with large scale, heavy coats of hair, and mature quite early.

270. The Herefords take their name from the county of Hereford, England, where the breed originated. They are typically a beef breed, hardy, early maturing, and well suited to range conditions. In milk-production they are very poor. The red body color and white face are well-fixed marks for the breed. (See Fig. 123.)

271. Aberdeen-Angus derive their name from two counties of northern Scotland. They are polled or hornless and noted for their fine beef qualities. Their place as a range breed is not yet established, though as feeders they have many friends. The body is very compact and more cylindrical than that of either Herefords or Shorthorns. The legs are short and heavy. Color is nearly always black. They are classed as medium milkers among beef breeds. (Fig. 130.)

272. Dairy Types are noted for their ability to produce large quantities of milk and butter, instead of flesh. They are noticeable for their long, deep couplings, triple wedge-shaped outlines, due to their clean-cut shoulders and broad, deep hind-quarters, clean-cut limbs, slender necks and sharp withers. They also have a full barrel, indicating strong constitution, and well-developed digestive systems, well-developed udders, and a capacity to yield a quantity of milk and butter on moderate feed. The important dairy breeds are the Jerseys, Guernseys, Holstein–Friesian, Ayshires and Dutch Belted.

273. The Jerseys and the Guernseys are natives of the islands of these names in the English Channel. The typical color for the Jersey breed is described as fawn, gray, and silvery fawn. White marks are not infrequent. The tongues and switch of the tail are typically black in pure-bred Jerseys. In conformation, the Jersey adheres strictly to the dairy-type characteristics. The weight of the cows averages between 650 and 850 pounds. Their milk is noted for its richness in butter-fat, a fair average being close to 4.5 per cent fat in the milk. As a beef producer, the Jersey is very poor. A number of famous Jerseys have records ranging from 700 to 1,000 pounds of butter in a single year.
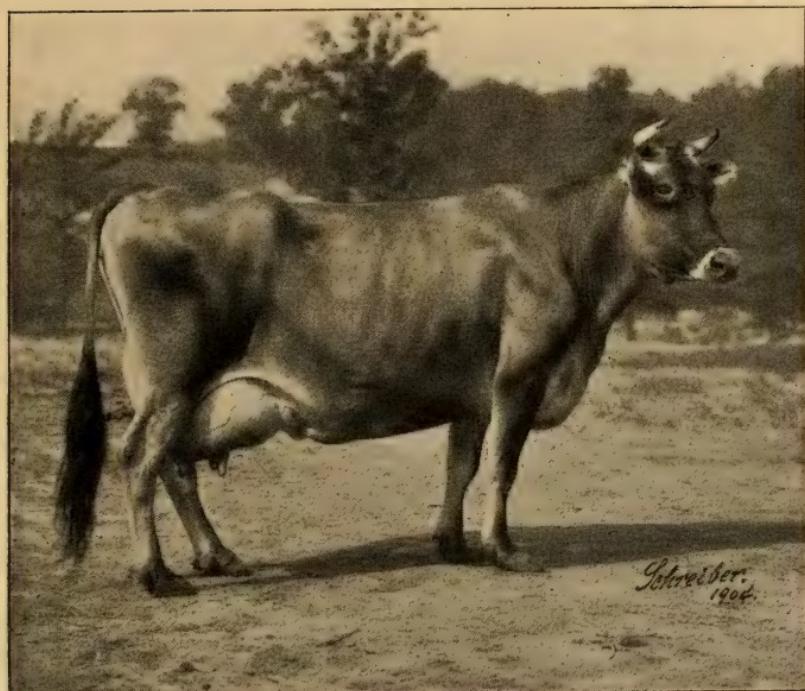
Fig. 131. Horetta D.

OFFICIAL MILK, FAT AND BUTTER YIELDS

Days	From	Milk		Fat		Estim'd butter*	
		Total	Daily average	Total	Daily average	Total	Daily average
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
120	June 16-Oct. 13. . .	5,802.7	48.35	280.16	2.33	330.03	2.75
30	Aug. 28-Sept. 26 . .	1,442.8	48.09	73.68	2.45	86.94	2.90
7	Sept. 17-Sept. 23 . .	335.2	47.90	17.67	2.52	20.85	2.98
1	Aug. 13	50.65	. . . .	3.13	. . . .	3.71	. . . .

274. The Holstein-Friesian, or simply Friesian, as they are called in their native country, Holland, is a splendid dairy type with large frame. The color is black

* In calculating the amount of commercial butter, add one-sixth to the net butter-fat, to allow for the moisture in the butter.

POINTS AND MEASUREMENTS TO BE OBSERVED IN- JUDGING CATTLE

1. Mouth.
2. Lips.
3. Nostrils.
4. Muzzle.
5. Face, from muzzle to poll.
6. Forehead, from eyes to poll.
7. Eye.
8. Cheek, side of head below
9. Jaw.   [eye.
10. Throat.
11. Brains.
12. Ear.
13. Poll, top of head.
14. Horns.
15. Neck.
16. Neck, lateral view.
17. Breast or bosom, front of chest.
18. Fore flank, rear of arm.
19. Dewlap, loose skin, underneath the throat.
20. Brisket, point of chest.
21. Withers, top of shoulders.
22. Shoulder point.
23. Neck or collar depression in
24. Elbow.   [front.
25. Chest cavity inclosing vital organs.
26. Arm, portion of leg between shoulder and knee.
27. Knee.
28. Cannon or shank-bone, between knee and ankle in fore- or hind-leg.
29. Hoof.
30. Spinal column, backbone.
31. Barrel or coupling, middle-piece.
32. Loin, muscle covering the short ribs.

33. Hooks or hips.
34. Crops, depression behind shoulder.
35. Fore-ribs.
36. Girth at flank.
37. Girth at heart.
38. Chine, between withers and loin.
39. False or floating ribs.
40. Belly.
41. Milk-veins, branched and tortuous ducts running forward beneath the barrel.
42. Orifices through which the milk veins enter the abdominal walls.
43. Midribs.
44. Abdominal depth, indicating digestion and constitution.
45. Tail head.
46. Pin bones.
47. Escutcheon, covered with fine hairs.
48. Buttocks.
49. Twist where hair turns on thigh.
50. Gaskin or lower thigh.
51. Brush.
52. Thigh.
53. Stifle.
54. Flank.
55. Udder.
56. Teats.
57. Hock.
58. Navel or umbilicus.
60. Pelvic arch or sacrum, the arch bone between the loin and crupper.

MEASUREMENTS.

A. Width of forehead.
B. Width of neck.
C. Width of breast.
D. Length from pin bones to shoulder point.

E. Height at withers and hooks.
F. Girth at flank and navel.
G. Length of barrel depression.
H. Width of hooks.
K. Length of hind-quarters.
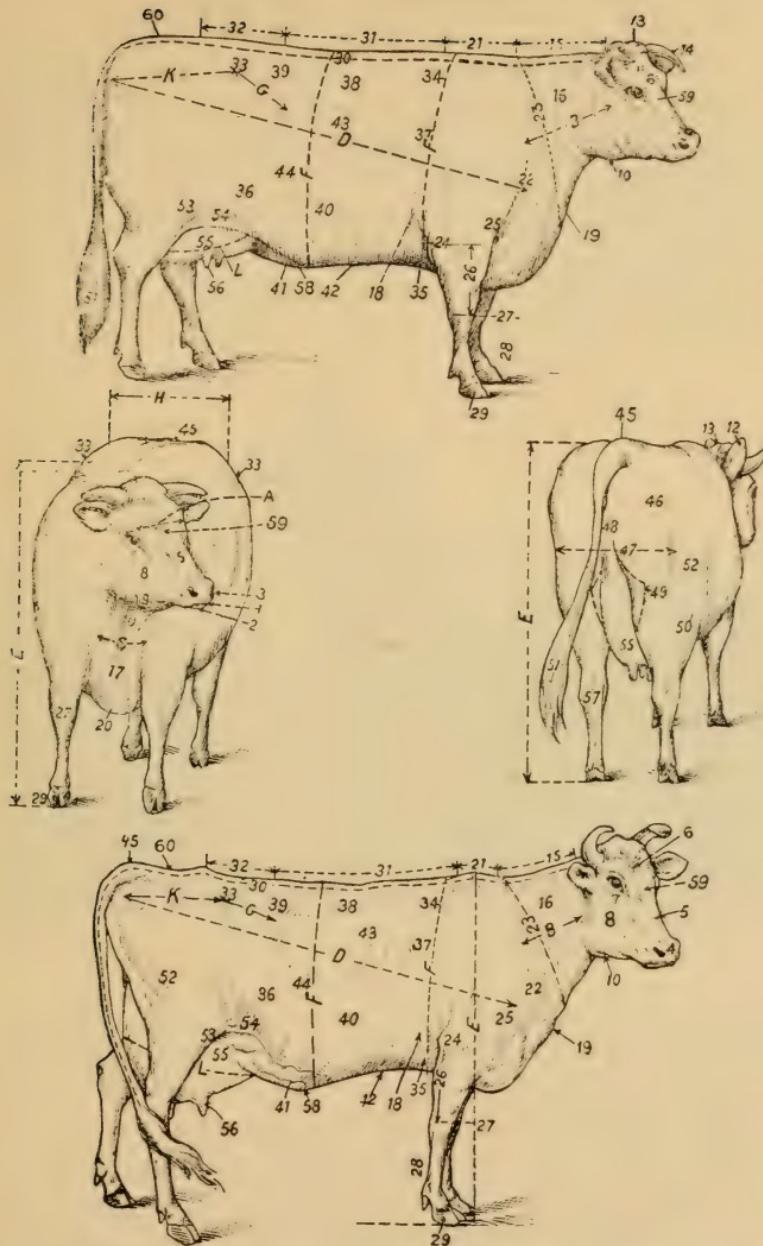
Fig. 132. Points and measurements to be observed in judging cattle.

and white, sometimes the white, sometimes the black, prevailing. In quantity of milk this breed excels all others. Colantha 4th's Johanna (Fig. 125) is credited with 27,432.5 pounds of milk in twelve months, which is the world's record. A good cow is expected to produce from 7,000 to 9,000 pounds of milk in a year. A cow that does not produce 4,000 or 5,000 pounds of milk a year is likely to be unprofitable. While the

Fig. 133. "She is broad on top." Courtesy of Department of Agricultural Extension, University of Ohio.

milk from Friesian cows is not so rich as that afforded by the Jerseys and the Guernseys, the total butter-fat is equally great.

275. Dual-purpose Breeds are intermediate between the beef and dairy types. The cows afford considerably more milk than the calves can use, and the body form is such that they dress out a good quality of beef. The breeds most usually classed as dual-purpose ani-

mals are Red Polls, Brown Swiss, Shorthorn and Ayeshires.

276. Judging Cattle. To become a good judge of stock one should study to find out the form and habits that represent useful qualities. The diagram in Fig. 000 should be closely studied, with two or three animals at hand for comparison, in training the judgment on the useful points.

CHAPTER XXVIII

TYPES AND BREEDS OF HORSES

277. Prehistoric Horses. The skeletons of horses existing in prehistoric times, ages and ages ago, are found in western North America, from Texas to British Columbia, also in England and France. Some of these early horses had toes. The little horny thickenings of

Fig. 134. Prehistoric horses. To show increase in size   A and B, Early forms; C, a later and larger form, about four and one-half hands high; D, the "forest horse." Drawings constructed from a study of the geologic remains, by Professor Osborne.

Fig. 135. Trotting stallion, Carmon, 32,917. The first sire selected for use in the experiments of the Department of Agriculture to develop an American breed of carriage horses.

the skin just above the knee of the front legs (chestnuts) and below the fetlock of the hind legs (ergots) are marks of the toes that were in the feet of the prehistoric horses. The horses which we have now are thought to have descended from the Old World stocks. (Fig. 134.)

278. Valuable Qualities in Horses. The horse is invaluable on the farm or in the city. He is stout, quick, intelligent, and more faithful than any other animal used for bearing burdens. Horses and mules are necessary for heavy hauling and plowing. Other forms of power are cheaper or more desirable in many cases, but there will always be work for the horse.

279. *Horses Should Be Selected for the work they are to do. Different kinds of work require different kinds of horses. A horse is of no particular value except for what he can do. To fulfil his mission he must travel. If he can draw a buggy containing one or two persons at the rate of ten miles an hour, he is valuable as a roadster. Another horse that can draw his share of a load weighing upwards of a ton, even though he moves slowly, performs an equal amount of actual work, and is just as useful to his owner as is the roadster. Since all horses are valuable because they travel, although at various rates and under widely varying conditions, it will be interesting to make a study of those parts of the horse's body directly connected with his locomotion.

280. Use of the Muscles. It is not difficult to understand that, with the horse as with ourselves, all motion is the result of the action of the muscles. About 40 per cent of the weight of an ordinary horse is muscle. All muscles concerned with locomotion are attached to bones, and when they contract they cause the bones to which they are fastened to move. The lower part of a horse's legs are nearly all bone, but the muscles in the body and upper part of the limbs are attached to various parts of the bony construction by tendons, and can thus produce a motion of the parts located some distance away. When contracted, the muscles we are discussing are about three-quarters as long as when at rest. The amount of motion produced by the action of the muscles of, say one of the horse's legs, will depend upon the length of the muscles and the

*Paragraphs 279 to 285 are taken by permission from a leaflet on "The Horse," by Prof. F. R. Marshall, published by the Ohio State University.
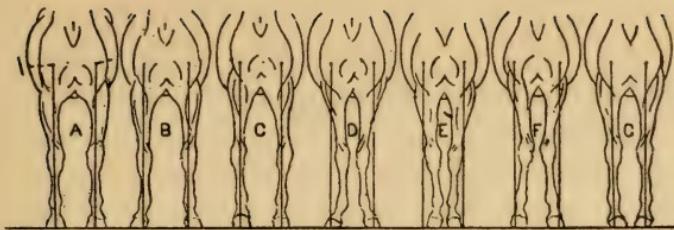
Front view of front legs. A shows correct conformation; B to G, common defects.
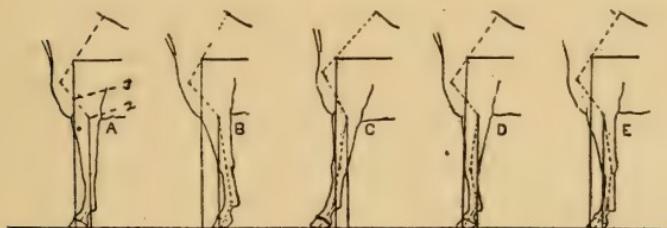
Side view of front legs. A shows correct conformation; B, foot too far back; C, too far forward; D, knee-sprung; E, knock-kneed.
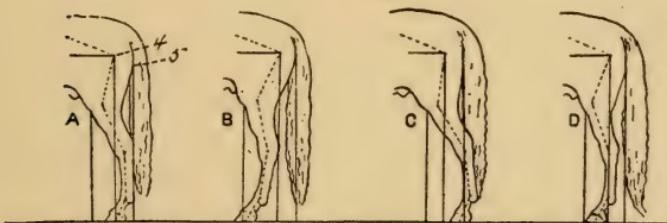
Side view of hind legs. A shows correct conformation; B to D, common defects.
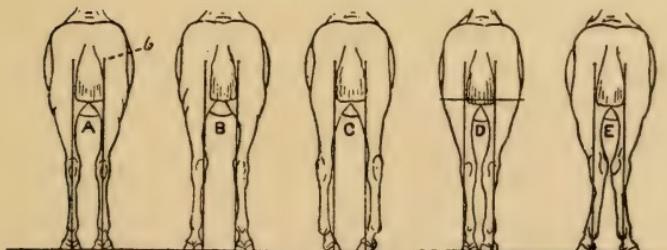
Rear view of hind legs. A shows correct conformation; B to E, common defects.

Fig. 136. Proper and improper positions of horses' legs, while standing.

length and the relation of the bones to which they are attached. The common idea among students of this subject is expressed in these words, "Long muscles for speed, short muscles for power." We have already seen that a long muscle enables a horse to get over ground rapidly. A short muscle, however, is not powerful because it is short, but because in horses constructed on that plan the muscles are thicker, containing more fibers, all of which pulling together when contracted exert a much greater pulling force than will a long, and more slender muscle. It is because of this that in buying horses to draw heavy loads we look for large and heavy muscles, while in roadsters we must attach importance to the length of the muscles.

281. Muscles of the Hind-quarters. The most of a horse's muscle is in the hind-quarters. This may be a surprise to you, but the next time you have an opportunity to see a horse pulling a very heavy load, study him carefully. You will be impressed with the idea that most of the work is being done with the hind legs. When the hind foot is moved forward the toe rests on the ground, and the leg is bent at the hock joint; if the toe does not slip, and the horse is strong enough for his load, the muscles above, pulling on the tendon fastened to the back and upper point of the hock, will close the joint, or, in other words, straighten the legs, and cause the body to move forward. It is by the performance of this act at every step that the horse moves, although, of course, the strain on all the parts is much greater when pulling very hard. This will also show the necessity of having large, broad, straight joints, and legs that give the horse the most secure footing. You have probably also noticed when driving that many

horses put their hind foot on the ground in front of the mark left by the fore foot, and the faster they go the greater will be the distance between the marks made by the fore and the hind feet. This shows that the length of a step is determined by the hind-quarters; it also explains the need of large, strong hocks, and legs that are not so crooked as to seem weak, or so straight as to lessen the leverage afforded by this very wonderful arrangement of the parts.

282. Body Form. Then there are some other things that are desired in all kinds of horses. One of these is a short back, that is, short from the hips to the top of the shoulders (the withers). From what we have learned of the hind parts we know that the horse is really pushing the rest of his body along. If the back is short and strong, instead of long and weak, the whole body will move more easily and rapidly in obedience to the force produced in the hind parts.

283. The Fore-legs. Although the hind parts have most to do with the horse's traveling, we must not forget that the front parts are also very important. No matter how much muscle a horse has, or how strong his hocks are, if there is anything seriously wrong with his front legs, he cannot travel, and so derives no benefit from his good parts. Some horses may be seen whose knees are not straight, others, when looked at from in front, show that their feet are not in line with their legs. Such animals are more likely to strike one leg with the opposite foot, thus making themselves lame and unable to do any work.

284. Horses' Feet. There are a great many interesting things about a horse which cannot be told here, but which you may learn at home, or from some neighbor

who keeps good horses. We will, however, say something about horses' feet. Inside a horse's hoof there are some very sensitive parts, resembling the attachment of the finger-nail to the finger. When anything gets wrong with the foot, these parts cause a great deal of pain, and even though the horse is otherwise perfect, the pain in his feet makes him too lame to travel. Horses with large, wide feet, that are wide across where they touch the ground when you look at them from behind (or in the heels), are not likely to have this trouble.

285. Style in Horses. Even though you have never studied horses, you have seen some that impress you as being more beautiful than others. No matter what kind of work is to be done, it is desirable to have a horse that looks well. Of course, it will depend upon whether the horse is thin or fat, and upon the grooming he has had, but you will usually find that the horses which attract you have rather long necks that rise upward from where they leave the body; the head, too, instead of being set on straight up and down, will have the nose pointed a little forward; the ears will be rather close together, and the eyes larger and bright-looking.

286. The Draft Type is becoming more popular wherever horses are used. They are better suited to farm work and the heavy hauling of large cities. Good draft horses have large size, blocky build, short legs, broad backs and quiet tempers. Percherons, Clydesdales, English shires and Belgians are leading representative breeds of the draft type.

287. The Percheron is now the most popular draft breed in America. They are docile, intelligent, active, and have excellent feet; are heavy in weight, and

steady pullers under load. Typical specimens of this breed run from fifteen to sixteen hands high. The color is generally gray, though blacks are often met.
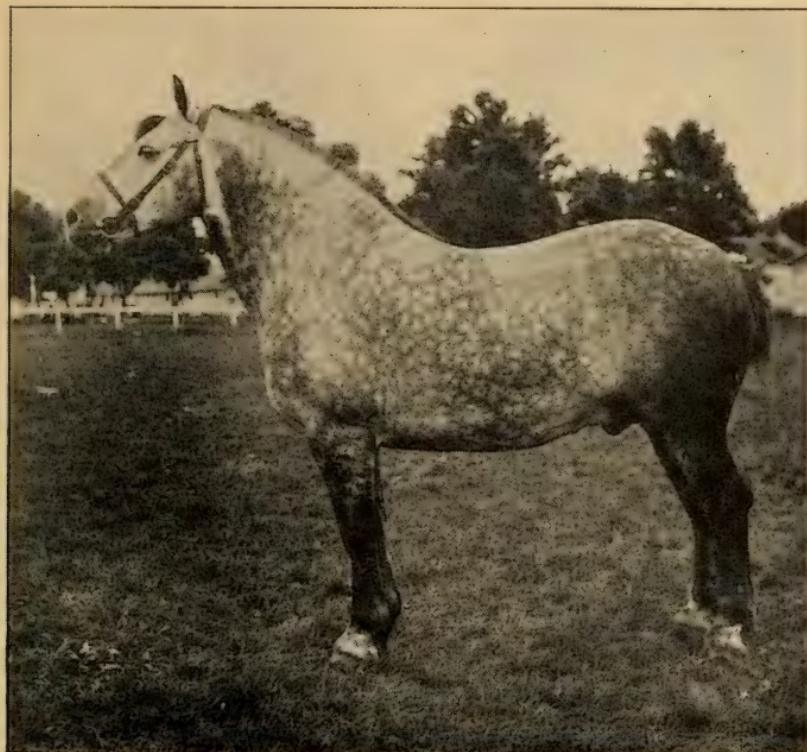
Fig. 137. Percheron, Medoc, 30,986. First in class at Iowa, Minnesota, and Wisconsin State Fairs, 1903; also one first and one second at Chicago International, 1903.

288. The Clydesdale is the recognized draft breed of Scotland, taking their name from the river Clyde. Usually they have smaller bodies and longer legs than the Percherons, which is supposed to allow more action.

289. Coach Types are sometimes referred to as heavy harness horses. The most popular breeds are the

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Hackney, or English Coach, Cleveland Bays, French Coach and German Coach.

290. Saddle and Driving Horses are very popular because of their quick action. There are several strains
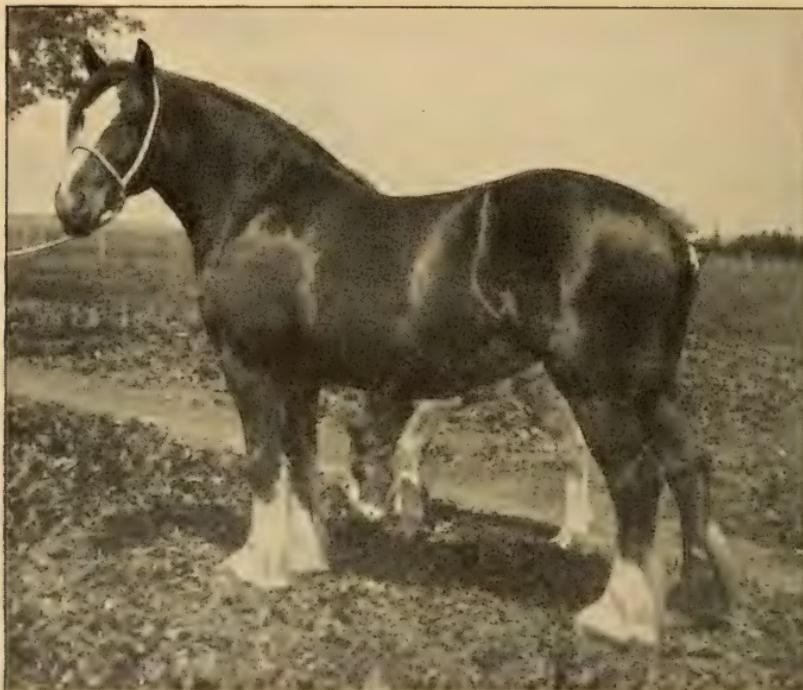
Fig. 137. Clydesdale mare, Princess Handsome. Winner of first prize three years in succession at Chicago International Live-stock Show.

of driving horses, all derived in part from the Arabian horses. As a result of superior breeding, the English thoroughbred and the American trotting horses have come to be better movers than the original Arabian stocks. There are several strains of the American trotting horses, such as the Hambeltonian, the Wilkes and the Morgans. The native "Mustangs," found in western

America by the early explorers, are supposed to be the descendants of early importations made during the Spanish conquest of Mexico.

Fig. 139. Hackney horse, Lord Burleigh. One of the greatest of modern
show horses

291. Ponies. Besides the ponies owned by the Indians of America, the little Shetland island horses are called ponies. These "Shetlands" are small because they have been forced to live on the coarse and scant grasses of the cold regions of north Scotland.

292. Judging Horses. Fig. 136 illustrates the proper and improper position of the legs of horses. In studying horses this should always be closely observed. Get two horses together and closely contrast the various points. Fig. 140 gives the names in common use for the various parts of a horse.
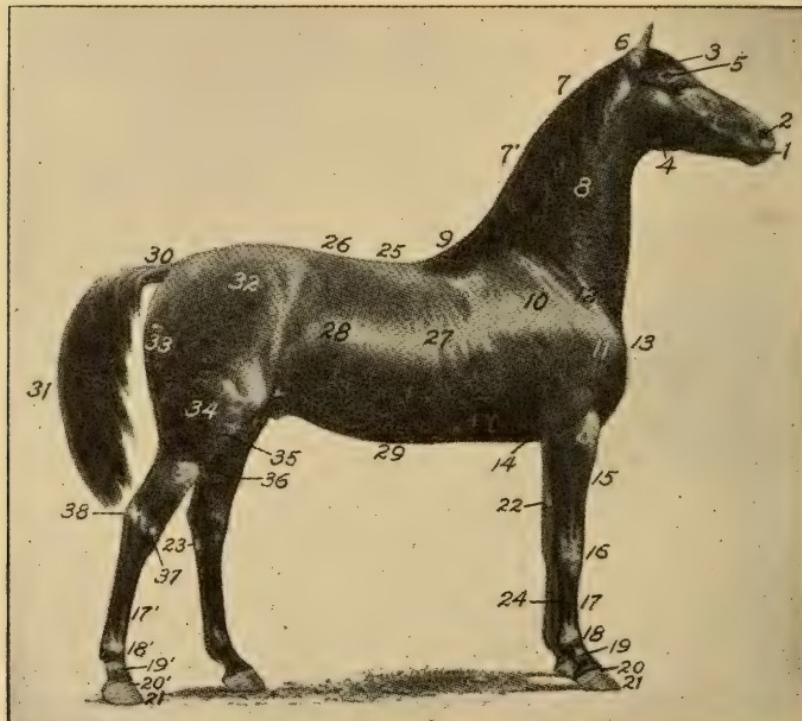
Fig. 140. Typical horse, showing names of the points.

1. Muzzle.
2. Nostril.
3. Forehead.
4. Cheek.
5. Temple.
6. Poll or nape of neck.
7-7'. Crest.
8. Neck.
9. Withers.
10. Shoulder.
11. Point of shoulder.
12. Slant of shoulder.
13. Breast.
14. Elbow.
15. Fore-arm.
16. Knee.
17-17'. Cannon bone.
18-18'. Fetlock.
19-19'. Pastern.
20-20'. Coronet.
21. Hoof.
22. Chestnut.
23. Ergot.
24. Splints.
25. Back.
26. Loins.
27. Chest.
28. Flank.
29. Belly.
30. Back.
31. Tail.
32. Croup.
33. Buttock.
34. Thigh.
35. Stifle joint.
36. Gaskin.
37. Hock.
38. Point of hock.

293. Care of Horses. Horses are intelligent and nervous animals, and should be handled with impassive judgment. Your treatment should convince him that you are his friend, as well as his master. If a horse shies, or becomes frightened, soothe and encourage him. You cannot whip terror out of a horse, nor courage into one. Before you check a horse's head into an unnatural position try it on yourself. Read "Black Beauty," and the story of the Bell of Justice in Longfellow's poem, "The Bell of Atri."

CHAPTER XXIX

TYPES AND BREEDS OF HOGS

294. Some Hogs Should Be on Every Farm. Hog flesh may be produced more cheaply than other kinds. There is very little waste in a hog carcass, because they are built so compactly. Hogs "dress out" seventy or eighty-five pounds of palatable products per hundred pounds live weight, varying according to the condition and kind of animal. With hogs, meat-producing quality is the valuable feature in all breeds. We consider not only the gross weight, but the form that will dress out the greatest per cent of high-priced cuts, and a small per cent of waste.

295. Food of Hogs. The hog will eat many kinds of slops and waste products that no other animal will. A range or pasture, clean, roomy pens, and some grain feed, with shelter for hot or extreme cold weather, are necessary to keep hogs healthy and growing. Some pasture should always be provided for hogs in winter
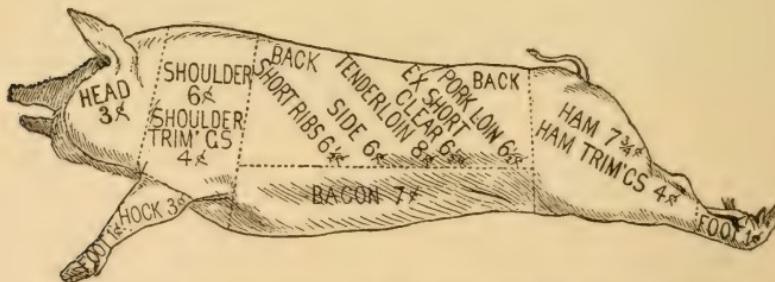
Fig. 141. Comparative values of the different cuts as used by the retail butchers of Chicago.

(214)

and summer. Oats, rye and wheat make good winter pasturage.

296. Lard Hogs. The hogs with large, spreading hams and shoulders, short bodies and broad backs, thick neck and jowls, with deep layers that contain a large amount of lard-bearing tissue as compared with the lean cuts, are called lard hogs. The Poland-Chinas, Berkshire, Duroc-Jerseys and Chester-Whites belong to this class.

**297. Bacon Hogs** are long in body, deep in sides, with comparatively narrow back, narrow, light hams
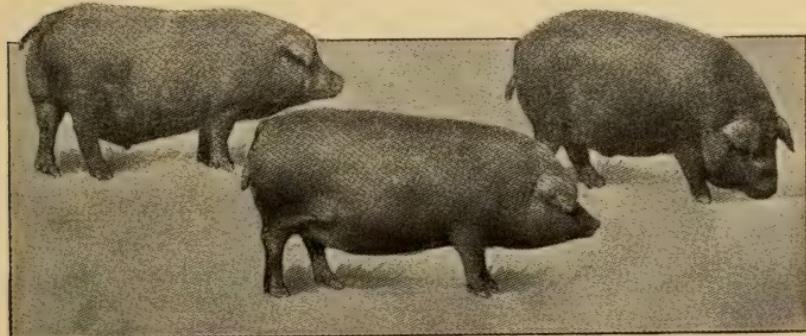
Fig. 142. Three representative Duroc-Jerseys.

and shoulders, and light, muscular neck. They lack the deep layers of fatty tissue found in the lard hogs. They have a strong muscular development, and hence dress out a large per cent of lean meat. Bacon hogs furnish a large per cent of the expensive cuts, such as choice hams and breakfast bacons. The Yorkshires and Tamworths are the leading breeds belonging to this class.

298. Duroc-Jersey. The Duroc-Jersey breed has probably descended from several strains of red hogs. The hair is coarse, and ears lapped forward. The back is
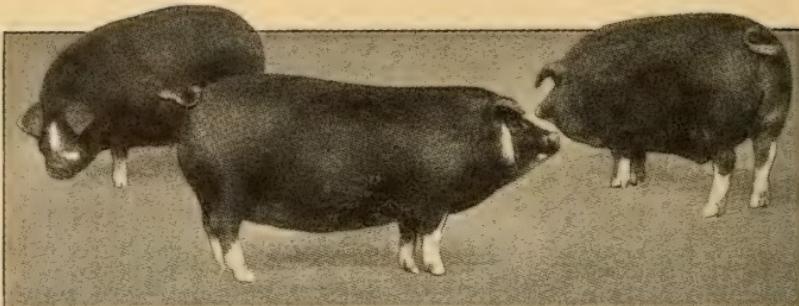
Fig. 143. Three representative Poland-Chinas.

short. slightly arched. and supports a broad, well-rounded body. The shoulders and hams are very heavy and thick-fleshed. Duroc-Jerseys are splendid feeders and good grazers and are justly popular in all sections.

299. The Poland-China breed is a native of Ohio. The color is black, with white points on feet and head. The ears are lapped, jowls are large, and the back has a gradual yet moderate arch the entire length. The body is shorter, but more spreading than in the Berkshire. As a rule, the sides and hams contain a smaller per cent of lean meat than the Berkshires. The pigs of this breed mature early, and as feeders under confinement, are rated among the best, and are especially liked
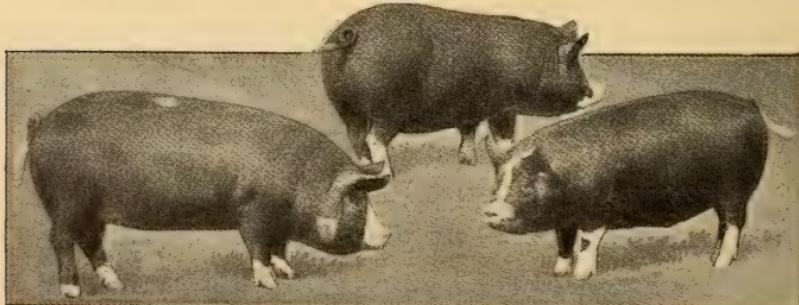
Fig. 144. Three representative Berkshires.

in the corn-belt states. They are typically representative of the lard-hog type.

300. Berkshires take their names from a shire or county of England. Berkshires have erect ears, a black body, generally with a white streak in the face or jowl, and four white feet. The back of the Berkshires is nearly straight, with moderate breadth. The barrel is long, with slightly arched ribs and deep sides. They are strong and active and are good grazers. The Berkshire is a good feeder and affords a good quantity of bacon.
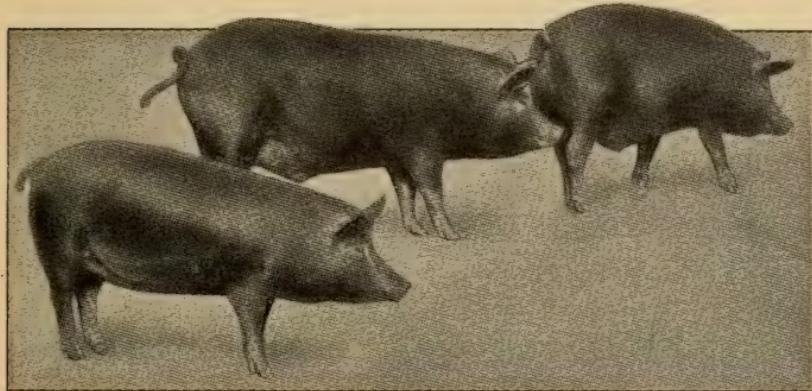

Fig. 145. Three representative Tamworths.

301. Tamworth. The native home of the Tamworth breed is in the counties of central England. They are typical of the bacon type of hog, so popular in some sections of England and Canada. With the increasing high prices for fancy bacon, they are becoming more widely recognized than ever before. The color is red. The back is long, while the sides are moderately deep and contain a large amount of "streak-o'-lean" bacon. The hams and shoulders are without the large amount of external fat, so noticeably present in Poland-Chinas and Duroc-Jerseys.

CHAPTER XXX

TYPES AND BREEDS OF SHEEP AND GOATS

302. Uses. Sheep and goats are valued for wool and mutton. In some countries goats are kept not only for mutton and hair, but to supply milk. Sheep and goats are great grazers. They will make more out of a pasture than any other class of animal, consuming not only the grass, but also many of the weeds and leaves of shrubs. Sheep are grown in large herds in the western states, primarily for wool. In recent years many farmers in the South have found small flocks of sheep or goats valuable additions to the stock of their farms.

303. The Wool produced by the different breeds differs much in quantity, quality and character. In some strains of the Merinos the clip of wool may equal one-fourth or even one-third of the animal's gross weight. The wool is much less in the mutton breeds. The breeds

Fig. 146. Merino sheep. Champion flock at St. Louis Fair, Illinois State Fair, and Charleston, S. C., Exposition, 1902.

(218)

are usually divided into three classes, according to the length of the wool. The long-wooled breeds are represented by the Lincoln, Leicester and Cotswold, while
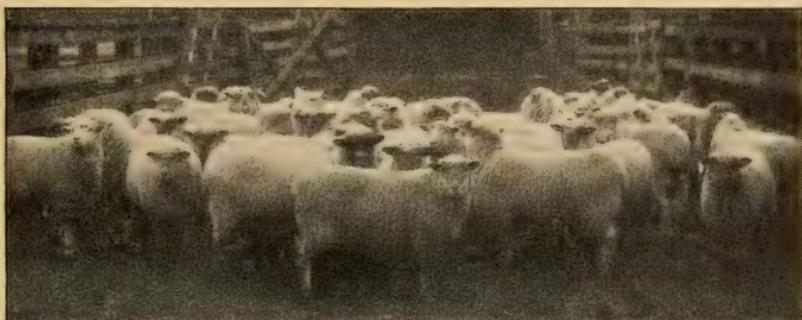
Fig. 147. Grand champion car-load of mutton sheep. Chicago Internationa. Exposition, 1901.

the short-wooled class includes the Southdown, Shropshire and Cheviot. The fine-wooled breeds are represented by the Rambouillet or French Merino, and Delaines or Spanish Merino. The fineness, as well as length of staple, is an important quality in wools. Dense fleeces, referring to the number of fibers per square inch, are desired by both the manufacturers and the sheep breeders. The dense fleeces afford more protection to the body, and deteriorate less from exposure to the rain, cold and dirt than the thin fleeces.

304. The Merino Breeds have descended from old Spanish stocks. They represent the highest type of wool producer. The fleece is fine, dense on the body, and uniform in length. The oil, or yolk, on the fleece causes the wool to catch a great deal of dirt on the outer layers, giving the animal a dark color. The Merinos are hardy, healthy and excellent foragers. They thrive even when the range is poor.

305. Mutton Breeds. The mutton qualities in sheep correspond to the same set of characters associated with the beef breeds of cattle. (See ¶ 271.) Sheep dress out from 50 to 60 per cent of their live weight in marketable prod-

Fig. 148. A famous Angora goat.

ucts. The leg, rib and loin cuts include nearly three-fourths of the total weight, and over 90 per cent of the value. Thus it is plain that a good mutton sheep means one with a blocky form, full, heavy legs, deep body, level, broad back, and short head and neck.

306. Goats. Goats are natural browsers, and not

grazers. They prefer the slender tips and twigs of young trees to grass, and on this account are often used to keep down the underbush in pastures. In the Southwest they find a climate well suited to their habits. The fibers of the fleece are very long and some coarser than fine wool. The fleece of the Angora goats is known as mohair. Milking breeds of goats have been highly developed in some countries. In the island of Malta the inhabitants depend very largely on goats for supplies of milk and butter. Milking-goats have been bred for centuries in Switzerland. Fine specimens give from four to seven quarts of milk a day.

CHAPTER XXXI

FARM POULTRY

307. Poultry Should be Raised at Every Home. Only a small outlay of capital is required to establish a paying poultry business. The natural food of nearly all members of the bird family is largely insects, small animals and fish. The eggs of all sorts of poultry from a rich, nutritious food. Ducks and geese produce a fine quality of feathers as well as food.

308. Hatching and Rearing Poultry. The growth of the germ in the egg begins at a temperature just a little below that of the bird's body. The temperature of the blood in chickens is given as 107.6° Fahr. or 42° C. In the brooding season the small blood-vessels on the breast of the chicken become more prominent. The time required to hatch, called the period of *incubation*. will vary with the freshness of the eggs and the kind of birds. The period of incubation for several kinds of birds is as follows:

Canary bird	14 days
Pigeon	18 days
Chicken	21 days
Guinea	25 days
Duck, geese and peacock	28 days
Turkey	28 days

309. Artificial Incubation. Artificial incubation is a very old practice in some countries. Incubators have become common in recent years wherever much

attention is given to the raising of poultry. It costs a great deal less to hatch, say, one hundred eggs artificially than it does to feed seven or eight hens. The additional advantage claimed for the incubator is that the
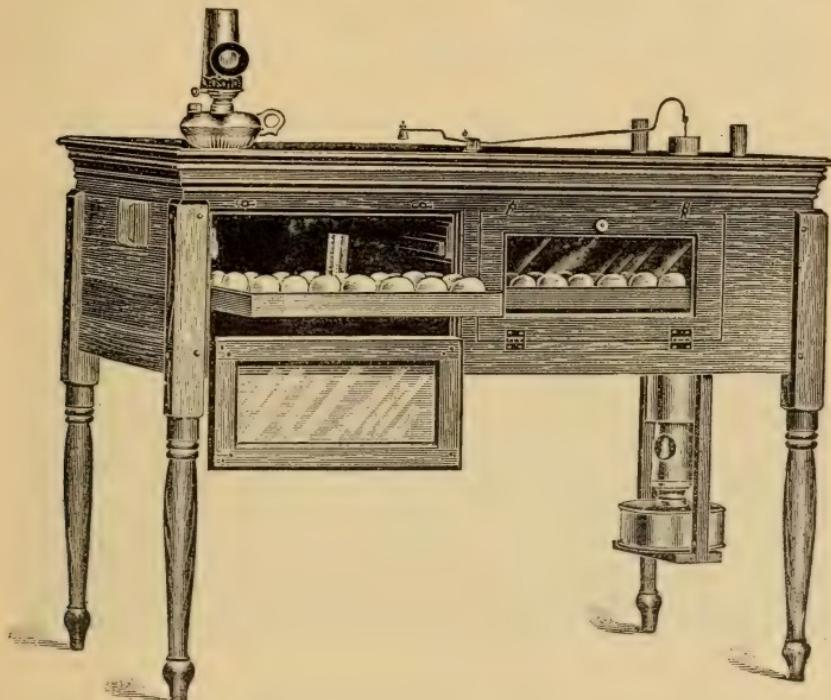

Fig. 149. A modern incubator.

hens soon begin laying, and that the chickens can be more easily cared for in brooders. There are two classes of incubators on the market,—the water-heated and the dry-heated. (Fig. 149.)

310. Poultry-Houses and Grounds. Poultry-houses and yards should be located on well-drained, and, preferably, on loose, sandy soils. They should be cleaned regularly to prevent the accumulation of filth that

might harbor disease-producing germs and parasites. The litter in the nests should be changed often. A dust box should be in every poultry-yard. The poultry-house may be simple in our climate, providing only a good coop, with the north and west sides closed, leaving the south wall partly open. The perches and nests should not be very high. (Fig. 150.)
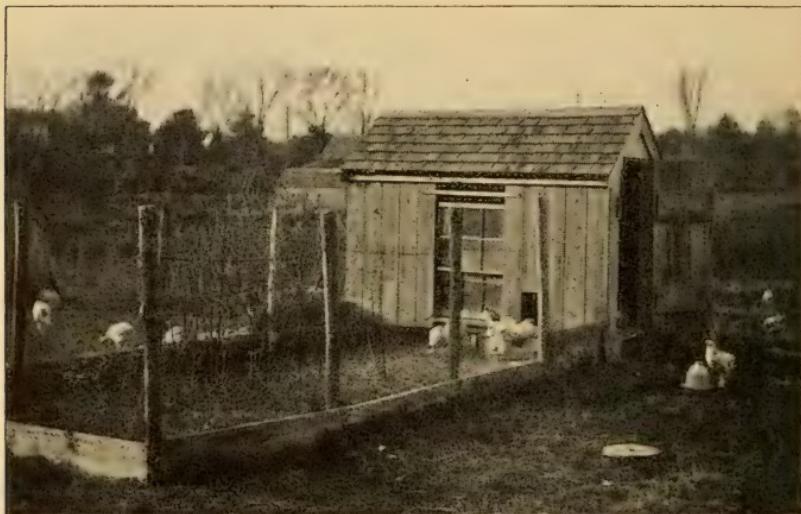
Fig. 150. A simple poultry house.

311. Feeding Poultry. The natural food of all domesticated fowls, and, in fact, nearly all birds, consists of insects, seeds and grasses. They require plenty of nitrogenous feeds, like insects, meat scraps, etc. For confined fowls, cottonseed meal, milk, or the tankage from the slaughter-house, make an excellent substitute for the animal feeds. Any of the grains may be fed to poultry. Green feed is very desirable for laying hens. All birds require grit to assist in the grinding of the feed in the gizzard. Coarse, sharp sand, crushed stone, or

cinders, etc., are desirable forms of grit. Crushed oyster-shells, or bones, supply the material for making the bones in young growing chickens and the egg-shells for laying hens.

312. Improving Poultry. To improve a breed or flock of poultry, use the eggs from the individuals having the desired characters. In breeding for increased egg-production, the number of eggs laid by a hen in a year is of far more importance than the color of the feathers. A hen laying 200 or more eggs a year is worth many times more than one laying from 30 to 50. There are many poor layers in all flocks. By using trap-nests for a full-year test the Maine Experiment

Fig. 151. A home-made trap nest.

Station found that in a number of spring pullets all bred pure to type, only 3 laid more than 200 eggs; 10 laid 175 to 200; 11 laid 150 to 174, and so on down; 11 laid 75 to 100; 6 laid 50 to 75, and 5 laid 36 to 49.

313. Preserving Eggs. Eggs decay as the result of the growth of germs in the rich substances of the egg. Warm temperatures favor the rapid development of the germs, hence eggs decay much faster in the summer. Just how the germ makes its entrance through the shell is not fully understood. Of the many kinds of egg-preservatives, none are so satisfactory as sodium silicate, commonly called "water-glass." The eggs may be packed away in a solution of about one part of water-glass to twelve parts of clean boiled water and kept as long

o

as desired. A mixture of salty lime-water is often used. In either case, the egg-shell should be punctured with a needle before boiling to prevent the shells cracking when placed in hot water.

314. Classes of Poultry. There are many classes and breeds of poultry, such as chickens, turkeys, ducks,

Fig. 152. White Leghorns — popular representatives of the egg-laying, or Mediterranean class.

geese, guineas, pigeons and peacocks. Some are raised largely for eggs, others for meat or feathers, and others still to satisfy a fancy. There are two well-marked types of chickens,—the laying type and the meat type. A combination of the two gives the general-purpose type.

315. Egg Breeds. The so-called egg breeds are natives of countries bordering the Mediterranean sea. They are of medium size, good layers, but often poor sitters when young. They are easily frightened, very hardy, active and make good foragers. The most popular representatives of this class are the Leghorns, Minorcas and Hamburgs.

316. The Meat Breeds are natives of Asia, hence are sometimes called the Asiatic breeds. They are large, heavy bodied, slow moving, having a gentle disposition, and are persistent sitters and good mothers. They are generally considered poor layers, though the pullets are often excellent layers. They are especially desirable because of the large size of the "broilers" and "friers." The best-known representatives are Brahmas, Cochins, Langshans and Faveroller, the latter a French breed.

Fig. 153. A Light Brahma cockerel. Typical representative of the Asiatic class.

317. The General-purpose Breeds, such as the Plymouth Rocks, Wyandottes and Dorkings, are usually of fair size, furnish meat of good quality, and will pro-

duce a liberal quantity of eggs under favorable conditions. It has never been found possible to completely combine into a single animal the milk and butter-fat
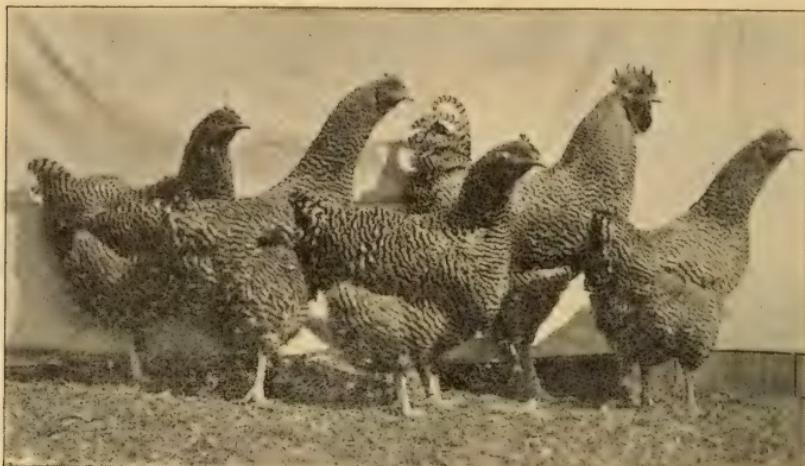
Fig. 154. Barred Plymouth Rocks. Favorites of the flock having their pictures "took."

qualities of the dairy types of cattle with the meatforming qualities of the beef breeds. The same body cannot be made to do both kinds of work to the same degree of perfection. So in poultry, we may blend, but cannot combine the egg- and meat-producing qualities. In selecting a breed, one should first decide what class of chickens will give the greatest return under the conditions,—a special-purpose egg or meat breed, or a blend of qualities. The general-purpose breeds have good egg-producing power, and produce good-sized friers and broilers. They are often used for mothers for the egg breeds.   (Fig. 158.)

318. Other Classes of Poultry. On many farms ducks and geese are raised for meat and feathers. There are great differences in the adaptability of the breeds.

Ponds of water are not essential for success with this class of poultry. The food should be given to these birds in a soaked or softened condition, because their crops are less perfectly developed than in chickens, hence do not thrive so well on hard grains.

319. Turkeys are native to North America. While they have lost much of their shyness and roving disposition by long association with man, they still must have the run of a large place for best success. The Bronze, White Holland and Black Norfolk are the most popular strains.

320. The Care of Young Poultry. Freshly hatched

Fig. 155. Turkeys come home to roost.
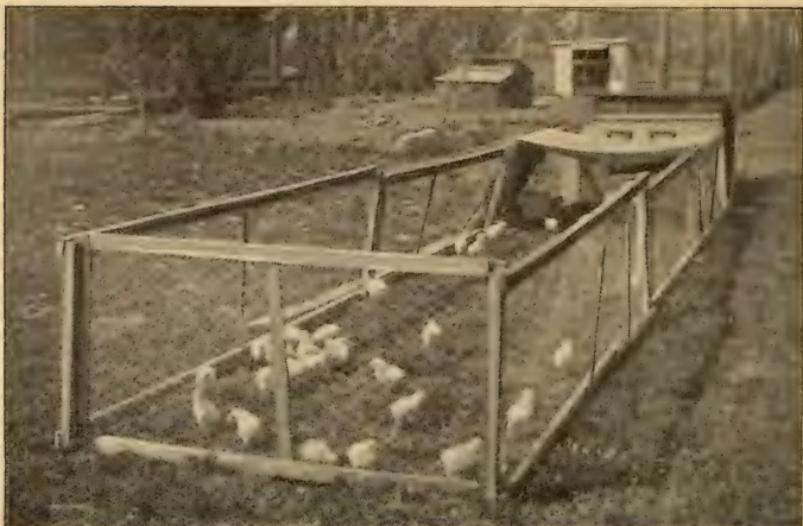
Fig. 156. An effective method of confining a "cluck" and her "peeps."

Fig. 157. Names of the points considered in describing chickens. 1, comb; 2, face; 3, wattles; 4, earlobes; 5, hackle; 6, breast; 7, back; 8, saddle; 9, saddle-feathers; 10, sickles; 11, tail-coverts; 12, main tail feathers; 13, wing-bow; 14, wing coverts forming wing-bar; 15, secondaries, wing-bay; 16, primaries or flight-feathers, wing-butts; 17, point of breast bone; 18, thighs; 19, hocks; 20, shanks or legs; 21, spur; 22, toes or claws.

fowls of all classes are quite delicate and therefore call for special attention. It is important that they be kept warm and dry until the feathers are fairly well developed. Unless the mothers are confined at night, they will most likely lead the young chickens into the wet, dewy grass in the early morning hours. Nothing is so important as warm, dry coops and regular feeding in rearing young chickens, turkeys, ducks or geese. The

feed should be specially prepared and offered five to
seven times during the day. No feed is needed for the
first day or two. The first food should be such as may
be digested without grit, such as ground grain or stale
bread just well moistened in skim-milk. It makes little
difference whether the milk is fresh or sour. They
should be given no more feed than they will clean up

Fig. 158. The Plymouth Rocks are often used for
mothers for Leghorns.

promptly. The feed supplies to young chickens, and older
ones as well, should contain ground bone or other form
of mineral matter. It is not so important that they have
animal food, as plenty of mineral matter and protein.
The latter may be of either vegetable or animal origin.
Investigations for the cause of death among young
poultry showed that 15 per cent had tuberculosis, due
no doubt to imperfect sanitation; 38 per cent had in-
testinal troubles, and 75 per cent had diseased livers,

influenced no doubt by unbalanced rations. (¶ 335). Shelter, feeding and exercise are points to be closely studied.

321. Judging Poultry. Fig. 157 shows the names of the more obvious points in chickens.

NUTRITION OF THE ANIMAL BODY

322. Nutrition of the Animal Body. The nutrition of the body of the farm animals is through the same processes which have heen previously described for the human body in the study of physiology. The feeds are taken in by the tongue and lips, masticated by the teeth, and digested in the stomach and intestinal canal.

323. Nutritive Substances. Animals require the same classes of *nutritive substances* to provide for the growth, repair and waste as in the human body. The substances which are taken into the digestive tract are not available for the nourishment of the body until they have been rendered soluble, absorbed and become a part of the blood. The various cells of the body absorb the sugars, proteids, and salts directly from the blood. These substances are absorbed through the cell‑walls, just as the yeast absorbs the sugar and albumen from the solution used in our early experiments.

324. Digestive Tract of Domestic Animals. There are important differences in the digestive tracts of the several classes of domestic animals, such that each is adapted to the different classes of substances upon which they feed and thrive.

325. Digestion by Fowls. Birds swallow their food whole without chewing. It passes first into the crop, where it is stored and softened by soaking. (Fig. 159 I). Then it passes into the thick-walled, muscular stomach or gizzard. The gizzard is supplied with powerful

muscles which break up the food eaten by the fowls. This is greatly aided by the sharp gravel which fowls swallow.

326. Herbivorous Animals. Vegetable food must usually be eaten in greater quantity to furnish the needed nutrients. In herbivorous animals the intestine is not only of a great length, but often has a large and chambered stomach, furnishing a large laboratory
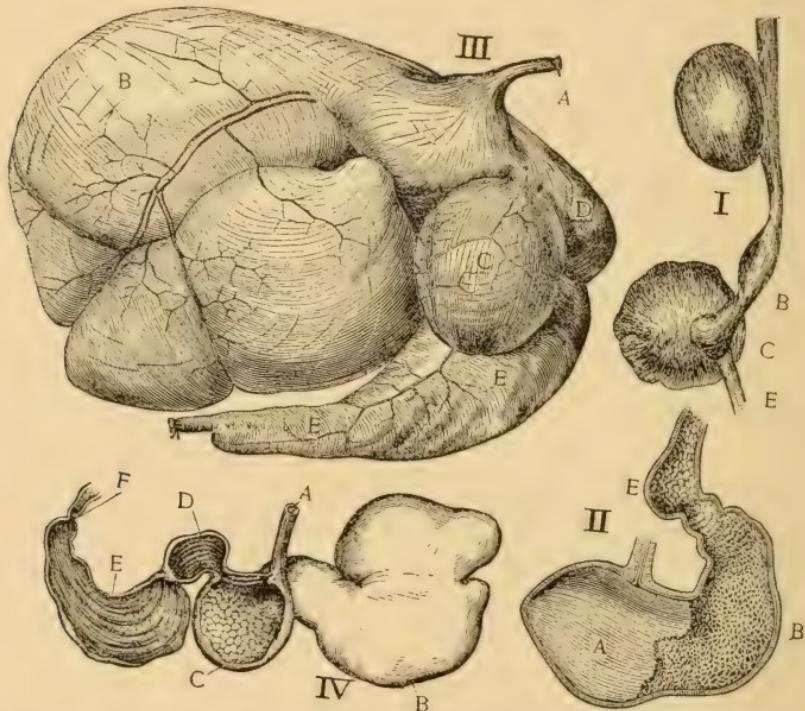

Fig. 159. Stomachs of some domestic animals. I, Crop and gizzard of fowl. A, œsophagus; B, glandular stomach; C, gizzard. II. Interior of horse stomach showing the two kinds of lining. A, left sac with tough white lining; B, right sac with soft red lining where the digestive juices are secreted; E, duodenum. III. Stomach of ox as seen from right upper race (Chauveau), and IV, Stomach of sheep with second, third and fourth divisions open. A, œsophagus; B′ right portion, and B″ left portion of rumen of first stomach; C, reticulum; D, omasum; E, abomasum, or true stomach; F, duodenum.

in which the digestive processes may be carried out. In the stomach of the horse, which is comparatively small, two regions may be distinguished, of which only the right or second part secretes digestive juices.

327. Ruminating Animals. In cattle and all split-hoof animals, the stomach has four more or less distinct compartments. (Fig. 159 III and IV). When a sheep or cow bites off a bit of grass, it is moistened with a small amount of saliva and swallowed without chewing, passing into the stomach or paunch. The stomach is a mere store-house. After a time the animal finds a quiet place, regurgitates a ball of grass, called a cud, which is slowly ground up between the molar teeth. This mass is again swallowed and passes into the second stomach, and then on to the fourth or true stomach where the gastric digestion commences. Ruminating animals continue the digestive processes for a longer period, chew their food finer, and, in general, digest a larger per cent of the protein, carbohydrates, crude fiber and fat, than non-ruminants, like the horse.

328. Nutrients in Feeds. The animal must secure from the feeds consumed all the substances needed for the support and growth of the animal body. The undigested parts form the waste. The nutritive substances actually secured from the feeds are classed as:

1. *Proteids* (albumin, albuminoids, amides, etc.).
2. *Fats* (oils, fats).
3. *Carbohydrates* (sugar, starches, gums, celluloses).
4. *Mineral Matters* (salts of the elements found in plants).
5. *Water*.

329. Functions of the Nutrients. The two chief uses of the nutrients in animal feeds are to supply:

1. Building material for muscle, bones, skin, etc., and repair the waste.

2. Heat to keep the body warm, and to supply energy for work.

The several classes of nutrients act in different ways in fulfilling these functions. The proteids from the muscles, tendons, gristle, hair and hoofs supply the proteids of blood, milk and other fluids, as well as the whites and yellow in eggs. The chief fuel or heat-giving ingredients are the carbohydrates and fats. These are consumed in the body or stored as fat to be used as occasion demands. The proteids may supply energy, though it is not supposed that they do so in the presence of sufficient fats and carbohydrates.

330. Fuel Value of Feeds. Starches, sugars, and fats, are burned (oxidized) in the body and yield heat and power, just as the same substances would if burned in the stove to heat the house or under the boiler to make the steam for the engine. The heat or energy is developed gradually as the needs of the body demand. Scientists have ways of determining the fuel value of substances, and for the purpose of comparison use as the unit of measurement the calorie (equal to the heat required to raise one kilogram of water one degree Centigrade, or one pound of water four degrees Fahrenheit).

331. Digestibility of Feeds. The value of a substance as a feed depends not only upon the quantity of the different kinds of nutrients contained, but also upon how much of the nutrients are in a form that they can be digested and used for the support of the animal body. The usefulness of a substance for feeding depends, then, not on its gross weight, but upon the amount of building material and heat energy which the animal

may extract from it. In comparing feeding substances we should not only know the actual amount of proteids, fat, carbohydrates, etc., contained, but what per cent of these substances is digestible.

In some digestion tests at the Oklahoma Experiment Station with cockerels, it was found that 79.4 per cent of the whole kaffir corn was digested, i. e., retained in the animal's body; in the same way 81.9 per cent of corn, and 64.1 per cent of cowpeas were digested.

332. Digestibility of the Nutrients. In the digestion tests mentioned above the composition of the substance fed, the nutrients digested and the waste, were as follows for each 100 grams consumed:

	Protein	Carbohydrates and fats
Nutrients in Kaffir corn...	11.88 grams	75.26 grams
Digested and retained	6.28 grams	73.90 grams
Undigested waste	5.60 grams	2.17 grams

In the above case it is noted that nearly all the carbohydrates were digested, though only about half of the proteids were used in the cockerel's body. Similar tests have been made for many kinds of feeds with many kinds of animals.

We see from this example that a chemical analysis giving the quantity of the nutrients is not an exact statement of the available nutrients. Appendix B gives the average results of many tests of the digestibility of American feeding materials. See also tables of composition in Appendix.

333. Ratio of Digestible Nutrients. In feeding animals it is important, as will be shown, to know the ratio of the digestible proteids, or flesh-forming nutrients, to the effective heat-forming substances. This ratio

is called the *"nutritive ratio"* and is taken to mean the ratio of the digestible proteids to the digestible carbohydrates plus 2.25 times the fat. (The fat has two and one-fourth times as much heat energy per pound as the carbohydrates.) Thus, in the preceding example, the nutritive ratio is 1:11.6, which means that the heat-producing nutrients are 11.6 times greater than the tissue-building nutrients.

<div align="center">Example with Cowpeas.</div>

	Proteids Grams	Carbohydrates Grams	Fats Grams
Nutrients in cowpeas......	21.44	62.16	2.38
Digested and retained	8.68	55.30	2.24
Undigested waste.........	12.76	6.86	.14

Ratio for digestible nutrients is 8.68:(55.30+2.24×2.25)=
$$8.68:(55.30+5.60) =$$
$$8.68: 60.90 = \text{nutritive ratio } 1:7.01$$

The ratio calculated according to the chemical composition is 1:3.1, which we see would be quite misleading, judging by the actual ratio of digestible nutrients which is 1:7.01.

334. Application of Ratios. The ratio of flesh-forming nutrients to the heat-producing nutrients should be suited to the condition and requirements of the animal. Animals at heavy work, where the muscle materials are being used up, require relatively more proteids than when merely at rest. Likewise, young and growing animals require plenty of building material, or animals which produce substances like milk, eggs and wool,—substances that contain large quantities of proteids,—should have food rich in proteids. (See table B in Appendix.)

335. Economy of Balanced Rations. When the proteids and heat - producing substances are supplied in the ratio approximately in which they are consumed, the ratio is said to be "balanced." There may be wide limits in the nutritive ratio without imparing the general health of the animals, but there may be a great difference in the cost of properly nourishing the animal. The feeds rich in proteids are very expensive, and it is desired that they be used only in the formation of nitrogenous products, and never to supply energy. The cheaper starchy foods should be used in sufficient quantity to supply heat and muscular energy. Thus, we see that by knowing something of the composition and digestibility of the common feeds, we may combine them in such proportions that the animal may be properly nourished at small cost.

336. Kinds of Rations. Rations are classed according to their effect on the animal, as regards bodily weight or function. The most usual designations are:

(a) *Deficient ration* is one in which the animal loses weight.

(b) *Maintenance ration* is one which allows just enough to keep the animal in good health without loss or gain in bodily weight. This is usually about three-fourths to one pound of nutrients to the hundred pounds of live weight.

(c) *Growing ration* is one allowing of a regular gain in weight. The amount af feed which a young animal may profitably consume varies widely, usually from 2 to 4 per cent of live weight.

(d) *Work ration* is one that will sustain an animal at work without loss of weight or vigor.

(e) *Dairy ration* is one that supplies the materials

for maintenance of bodily conditions, as well as those used in secreting the milk.

There are many other kinds of special rations, referring to the bodily needs of animals maintained under special conditions, such as egg rations, wool rations, etc.

337. Planning a Ration. Suppose it is desired to know how much and what kinds of feeds to give to a dairy cow of 1,000 pounds live weight, giving two gallons of milk per day. Turning to table of standard feeding requirements we have:

	Live weight pounds required	Total dry matter	Digestible nutrients		
			Pro-tein	Carbo-hydrate	Fat
Dairy cow, 16 lbs. milk..	1,000	27	2.0	11.0	0.4

The problem is to find the combination of feeds that will supply the above nutrients in approximately the amounts indicated. Suppose we have alfalfa hay, wheat bran and cottonseed meal. After studying the tables of composition and digestible nutrients as given in the Appendix, we may make a trial guess, with the result as follows:

Feeds	Amount	Dry matter	Digestible nutrients		Cost
			Proteid	Carbohy-drates, fat	
Alfalfa hay, dry.	10 lbs.	9.2	1.10	4.2	....
Mixed hay	10 lbs.	8.5	.44	4.4	....
Wheat bran	5 lbs.	4.4	.60	2.3	....
Cottonseed meal.	1 lb.	.9	.40	.4	....
Total	26 lbs.	23.0	2.54	11.3	....

The result shows that we do not have enough dry matter, and too much proteid by .54 pounds. The

latter is usually very expensive and would be advisable
only when the alfalfa was very cheap. Suppose we
decrease the alfalfa, increase the mixed hay, and leave
out the cottonseed meal, which may be done when we
feed rich nitrogenous hay, like alfalfa. Then we try:

Feeds	Amount	Dry matter	Digestible nutrients		Cost
			Protein	Carbohy-drates, fat	
Alfalfa hay.....	5 lbs.	4.6	.55	2.1	....
Mixed hay	20 lbs.	16.9	.88	8.9	....
Bran	5 lbs.	4.4	.60	2.3	....
Totals	30 lbs.	25.9	2.03	13.3	....

The result is quite close enough. Close observation
may suggest slight variations to suit the needs of differ-
ent animals. It should be understood that these "stand-
ards" are average, and that particular animals may
require more or less than the amounts indicated.

338. The Amount of Feed required depends on the
size and condition, and also on the individuality of
the animal. By many carefully conducted trials, inves-
tigators of feeding problems have made approximations
of the dry matter, protein, carbohydrates, etc., needed
per hundred or thousand pounds live weight of animal
per day. (See table of feeding standards in Appendix.)

339. Roughage and Concentrated Foods. According
to the per cent of digestible nutrients in feed stuffs
they are classed as *Roughage* and *Concentrates*. Sub-
stances like hay, which contain a large per cent of undi-
gestible substance, are called Forage or Roughage, and
those like the grains, cottonseed meal, etc., in which
nearly all is digestible, are called Concentrates. Rough-

P

age is desirable to give bulk to the ration. Straw is an
excellent roughage, yet if fed on straw alone, an animal
would be unable to eat enough to secure the needed
nutrients. If fed on concentrates entirely, the digestive
juice could not act on all parts sufficiently and disorder
would follow. Water and fiber give bulk to feeds.
Ruminating animals require about two-thirds of their
feed to be in the form of roughage. For horses, about
one-half should be in the form of roughage.

340. The Food Should Be Palatable. The food supplied
should be relished. A ration may be perfectly balanced
so far as its nutrients are concerned, and yet if it is not
palatable, good results may not be secured. One way
of making foods palatable is to give a change—change
in hay or in concentrates. In changing from one kind
of feed to another, however, the change should be made
gradually. Abrupt changes in feed are likely to throw
highly fed animals "off feed." Animals relish variety
at the dinner-table just as we do. The good effect of
green feeds in winter time is probably due in part to
this fact. Green feeds through the winter may be easily
supplied in nearly all parts of the South by sowing fall
oats or wheat. Green feeds aid the digestion of other
feeds.

341. Importance of Salt for Stock. Every good
farmer knows that his stock needs salt, and takes pains
to supply them. All classes of farm animals should
have salt where they can get it every day. Almost
every animal will take salt every day. Either fine
or rock-salt may be used, and, to prevent waste from
rains, it should, if possible, be under a shed. Ruminating
animals (sheep and cattle) need salt more regularly
and abundantly than horses. Dairy cows should always

receive special attention in this respect. Salt aids diges-
tion, improves the appetite, and lessens the danger
from disease. Small quantities of salt in the feed will
often stimulate the appetite of sick animals and acts
as a good tonic.

342. Preparations of Feeds. The extent to which
different feeds should be prepared by grinding, shred-
ding, soaking, cooking, etc., before feeding is, in many
cases, an open question. When grain is fed to ruminants
it is best to have it milled, but in other cases it is fre-
quently without advantages, except in the case of kaffir
corn. Kaffir corn should be ground for all farm stock.

343. Racial Peculiarities are observed in the way
different breeds dispose of the feed they consume above
that required for maintenance. This is important.
The extent to which an animal disposes of the feed above
that required for maintenance governs the profit or
loss in animal husbandry. It is this extra quantity of
feed that makes flesh, milk, eggs, or performs work.
If the maintenance ration be assumed to be eight pounds
of dry matter and the feed contains twenty-five pounds,
what becomes of the additional seventeen pounds
of feed? The Hereford steer would deposit it in the
loin steaks and thick quarters. The animals would
gain in weight. The dairy cow would probably not gain
in weight but use it in making the fat, sugar and curd
of milk. An animal is valuable for its ability to trans-
form large quantities of crude farm feeds into special
products, such as valuable cuts of meat, milk, wool,
etc., or perform labor.

344. Individual Peculiarities are also to be noted.
The average dairy cow will profitably use about six
pounds of feed above the maintenance ration. Many

animals will be able to profitably use only three or four pounds, while still others may return a profit on twelve or fifteen pounds. The intelligent feeder knows how to feed to get best results, but in every herd or flock there are "good feeders" and "poor feeders." The wise breeder notes the peculiarities in selecting his animals for propagation. "Like begets like," in habits as well as in form.

345. Skill in Feeding. The observant farmer or feeder will soon learn the peculiarities of his animals. He never feeds an animal so abundantly that the appetite will be lax at the next feeding. He will feed often and regularly. In fattening hogs, steers, etc., he begins with light rations, and increases gradually as circumstances suggest until the stock are on "full feed."

346. Pasturage. Wherever possible, provision should be made for stock to gather green food from pastures. It is a benefit to the fields to sow them in winter annuals and allow the stock to graze during dry weather. This is especially desirable for poultry, dairy cattle and hogs. In some cases it is profitable to haul the green feed to the stock, rather than pasture it. This latter practice is spoken of as "soiling" and the crop as a "soiling crop."

347. Shelter for Farm Animals. A simple shelter to shield stock and poultry from wet or cold weather is necessary on every farm. This need not be so elaborate and costly as those used in colder regions. Shelter reduces the cost of feeding. Exposure reduces the flow of milk in dairy cows, and the frequency of laying in poultry.

FARM DAIRYING

348. Farm Dairying. The dairy cow on the farm is a necessity, first and foremost, because she supplies food for the family which in quality and cheapness is without comparison. Milk and eggs supply the protein nutrients needed by the human body cheaper than meats. A pound of steak, a dozen eggs, or a quart of milk supply about the same amount of protein, yet the selling price of the milk, on an average, is less than half the cost of the others. Milk and butter are not only important foods, but valuable condiments used in many ways in rendering other foods palatable. It is these qualities that make a market for dairy products the world over.

349. A Natural Advantage of the South is the ease with which green feeds may be grown throughout the entire year. Many dairies are profitable without green feeds, yet every one recognizes that fresh green feed, either in pastures or in soiling crops, are great aids in increasing the flow of milk. Mild winters remove the necessity for expensive barns, and reduce the quantity of feed needed to keep the cow in splendid condition.

350. The Distinctive Quality of the Dairy Cow is her capacity to manufacture large quantities of milk, rich in butter-fat, from common feeds. A cow that does not give more than two gallons of rich milk per day should be discarded. The richness of the milk is always to be considered. The Babcock test (Fig. 160)

places easily at the disposal of every farmer a means of determining the butter-producing qualities of every cow in the herd. The success or failure of the farm dairy to yield a profit on the outlay for land, building, feed and labor, lies in the proper selection of the cows to compose the herd.

351. The Babcock Test is a simple means of testing the milk to determine the amount of butter-fat (richness) contained in a sample of milk. It takes its name from Professor Babcock, of the University of Wisconsin, who discovered the method of making the test. By its use the dairyman may learn which of his cows pay for their board. The milk from each cow is weighed, and a small sample used to determine the per cent of butter-fat. Knowing these two facts, the total butter-yield for each cow may be calculated. In this way the value of the cow is definitely known. It is easier and more reliable than a "churning test."
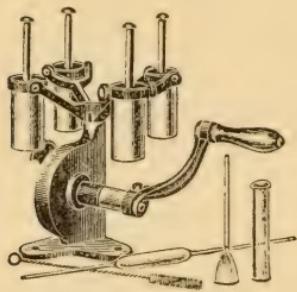
Fig. 160. Apparatus used in making the Babcock test.

In making the test, a measured quantity of milk is put into a special flask (Fig. 160A), and to this a small quantity of acid is added. By following a few simple operations, for which directions come with every machine, the per cent of butter-fat is read off directly on the graduated neck of the bottle. Knowing the per cent of butter-fat and the quantity of milk, the amount of butter in each cow's milk may be quickly calculated.

352. How Dairy Cows Are Valued. The dairy cow is valuable according to her ability to convert farm feeds

into milk rich in butter-fat. Creameries and dairies pay for milk according to the per cent of butter-fat, and not the mere gallons of milk.

352a. (*a*) Farmer "A" runs a small butter dairy. He bought a Babcock Test, and made a test of each cow's milk with the following results:

Name of cow	Average daily flow of milk	Per cent of butter-fat in average samples	Pounds butter-fat daily
	Pounds	Per cent	
Blossom	23	2.3	. . . . .
Flower	14	3.1	. . . . .
Nancy	31	4.2	. . . . .
Lily	20	6.5	. . . . .

Calculate the amount of butter-fat in each cow's milk. One pound of butter-fat is equal to one and one-sixth pounds commercial butter. How much butter would these cows make in ten months?

353. Other Uses of the Babcock Test. Creameries no longer buy milk by the "gallon," but pay so much a pound for the butter-fat. This does away with the temptation to water the milk. In cities, public dairies are required to sell pure milk, with a certain amount of butter-fat, usually not less than 35 per cent. By the use of the test, both the dairyman and the public officials may easily know if the milk is up to the required standard of richness. The butter in buttermilk is often a source of considerable loss. By testing the buttermilk, or skim-milk, the dairyman may know if his methods get all the butter.

354. Composition of Milk. Milk contains about 87 per cent water and 13 per cent solids, divided as follows: 5 per cent sugar, 3.3 per cent protein, 4 per cent

fat and only 0.7 per cent mineral matter, or salts. The milk from different cows varies considerably. The solids may be as low as 10 per cent or as high as 18 per cent. The protein (the substance that thickens and forms clabber) may be low if cows do not receive feeds sufficiently rich in protein. The fat varies, sometimes as low as 2.5 per cent and sometimes as high as 8 per cent. The legal standard required by state and city laws is 3 to 3.5 per cent fat, and 9 to 9.5 per cent solids other than fat. The composition of milk is but slightly changed by the feed a cow consumes. The feed does affect the quantity of milk, however.

355. How the Kind of Feed Affects the Flow of Milk. The feeding of dairy cows to increase the flow of milk has long been studied, both by the experiment stations and practical dairymen. The exact methods of scientific investigation where the feed consumed and the milk and butter produced are carefully weighed, teach that for the best results dairy cows should have:

(*a*) An allowance of green, succulent food, either by pasturing, soiling crops or silage.

(*b*) Some dry roughness in the form of hay, corn stover, or straw.

(*c*) Grains or concentrates supplying sufficient protein and carbohydrates to bring the ration to the normal dairy standard.

Succulent feeds promote the digestion of other feeds, and give flavor and color to the milk and butter.

Dry roughage has a wholesome effect on the health and general condition of the cows. The cow craves some dry feed which can be hastily swallowed, and while lying down at rest, be regurgitated and chewed over.

356. Changes in Milk. Bacteria are the active agents of change in milk. The souring of milk is due to the formation of acid by bacteria. When the acid accumulates in sufficient quantity, it combines with the protein to form the clabber. If bacteria are kept out of the milk, it will keep sweet indefinitely. The flavors developed in milk and butter are due to the presence of certain

Fig 161. Microscopic appearance of ordinary milk showing fat globules and bacteria in the milk. The cluster of bacteria on left side are lactic acid-forming germs. After Russell, Wisconsin Bulletin, No. 62.

kinds of bacteria. Some give the butter undesirable flavor, and some greatly improve the flavor. The flavor of butter, however, may be controlled by destroying all the bacteria in the milk or cream by Pasteurization. (¶ 367.) After the milk or cream has been freed from the desirable, as well as undesirable germs, by the process mentioned, it is then cooled and desirable ones

Progeny of a Single Germ ⊖ in twelve hours.

In milk allowed to cool naturally.

In milk cooled with cold water.

Fig. 162. Cooling hinders growth of bacteria. After Russel, Wisconsin Bulletin, No. 62.

are added and maintained at a temperature favorable to the development of proper flavors and texture in the butter. This is preferably between 60° and 70° Fahr. This practice is known as adding a "starter," and is used extensively in commercial butter-making. In the absence of commercial starters, a little sour milk will prove quite satisfactory.

357. Gravity Creaming. When milk is "set" to allow the cream to rise, it should be kept cool. The cream rises quicker and more completely if kept cool by ice or moist cloths. Gravity creaming leaves from 0.5 to 1.0 per cent of the butter-fat in the milk even when the temperature of the milk is kept at 60° Fahr. The rise of the fat globules of milk to form "cream" is due to the fact that fat is lighter than water or the milk serum.

358. Centrifugal Cream-ing. The cream separator

Fig. 163. A modern cream separator.

is a machine for separating the cream from milk while fresh. It separates cream much better, quicker and with less work than gravity creaming. Good separators leave only 0.1 to 0.2 per cent of the butter-fat in the milk. The separator also gives a cleaner cream than can be obtained by the usual methods. The effective-

ness of cream separators is due to the action of centrifugal force, which has a tendency to throw the heavier particles to the outside. Cream being lighter than skimmed milk, it is thrown to the center and the skimmed milk thrown to the outside of a rapidly revolving hollow ball.

358a. Farmer Smith milked ten cows, giving an average of 6,000 pounds of milk per year. He used the gravity creaming process and lost one-third to three-fourths pound of butter on every hundred pounds of milk due to imperfect separation of the cream. His neighbor advised the purchase of a cream separator which would leave only one-twentieth pound of butter-fat in the milk, telling him that besides saving the difference in butter-fat he would be able to feed his calves the fresh-skimmed warm milk. Estimate the difference and give your advice to Farmer Smith.

359. Sanitary Dairy Products. In the production of sanitary dairy products great care must be observed in the following particulars: (1) The healthfulness of the animals. (2) The healthfulness of the milker. (3) The cleanliness of the stables. (4) The care in milking. (5) The care in keeping the milk. Unless all of these conditions are carefully observed, sanitary milk-production is an impossibility.

360. The Healthfulness of the Animals. Unless the the dairy cow is in a healthy condition, she should not be expected to secrete a healthy milk. All of the blood which goes to the manufacture of milk must pass through the circulation, and if any diseases are present the blood is apt to take up the germs producing them, and in some cases these same germs have been found in the milk. It will, therefore, be noted that the first essential in the production of sanitary dairy products is the presence of a healthy herd of cows.

361. The Healthfulness of the Milkers. On account

of the fact that milk is peculiarly adaptable to the growth of germs, any one having a contagious or infectious disease should not come in contact with it. Germs are always present in such cases, as smallpox, typhoid fever, diphtheria, etc., and are certain to find their way into the product if the person afflicted is permitted to come in contact with the milk or butter.

362. Cleanliness of the Stable. At best, the stable is difficult to free from bacteria. The great natural enemies of bacteria are light and sunshine. The stable should be kept clean, and there should always be present an abundance of fresh air and sunshine. The dark corners of the stable, filled with dust, are the houses of millions of germs which finally find their way into the milk and make it unfit for human food.

363. Care in Milking. When milk first comes from a healthy cow it is clean, wholesome, and free from bacteria or germs. It is also known that it is possible to produce milk with comparatively only a few germs by the exercise of care in milking. The care in milking consists in clean hands and clean clothes on the part of the milker and the proper cleaning of the cow's udder before the milking begins.

364. Care in Keeping Milk. Milk is very susceptible to bad odors as well as germs, therefore, it should be removed to a cool, clean place as soon as milked. The milking should precede the feeding, as there is always more or less dust present in feeding hay, and other undesirable odors are present, when feeding silage or root crops. As soon as milked, the animal heat and animal odor should be removed by thoroughly airing and cooling the milk.

365. Churning. The size, consistency and number

of the butter-fat globules is not always the same. The object of churning is to cause these many, minute fat globules to unite to form larger ones. This is brought about by agitating the milk in such a way that the globules will rub against each other and unite. As temperature greatly affects the consistency of the

Fig. 164. Revolving barrel churn.

globules it also affects the nature of the result in churning. If the temperature is very low, the globules are hard and are less likely to adhere in the operation of churning. If the temperature is very high, it renders the globules quite soft and churning has a tendency to cause them to break up into even smaller particles. There are many other conditions besides the temperature that affect the "gathering," or "breaking," of the

butter-fat globules and the character or quality of the butter, such as the condition and breed of the cows, the feed of the cows, the temperature maintained during the ripening of the cream, the acidity of the cream and even the nature of the agitation given the cream in churning. As these conditions vary, so will the temperature giving the most favorable results in churning. Practical dairymen usually try to maintain a temperature near 59 to 65 degrees in churning. The preference will usually be for the lower temperatures because of the better quality of the butter, although it will require a longer time to churn. There are many styles of churns on the market, but expert butter-makers usually prefer some form of revolving box or barrel churn, claiming that it gives a butter with better quality. Where the agitation is produced by paddles the grain of the butter is not so desirable as in the open-centered churns.

366. Judging Butter. Butter is now judged by a scale of points just as the breeds of live stock and crops are. The points of most importance are (1) flavor, (2) texture, (3) color, (4) salt, and (5) package. Variations in flavor are due to several causes, such as breed of cows, individuality of cow, nature of feed, acidity of cream and kind of bacteria in the cream. Variations in texture are due chiefly to the nature of the feed and the temperature at which the cream ripens, and, also, the churning temperature, as discussed above.

367. Pasteurization. One way of keeping milk longer than could be done under natural conditions, consists in heating to a temperature of 160° Fahr. and then rapidly cooling. This method of treating milk is known as Pasteurization, and takes its name after Pasteur, the great French bacteriologist. The object

of heating and cooling is to destroy the majority of bacteria present, and prevent the others which are not affected at that temperature, from becoming active. The temperature given above is deemed sufficient to destroy all, at least all disease-producing, germs and is not high enough to affect the flavor of the milk.

368. Clarification. We have just observed the practice of freeing milk from bacteria in order to make it "keep" longer. Now let us note the practice employed in freeing the milk from undesirable foreign matter. It matters not how careful the milker is in doing his work, there is always more or less foreign matter, which passes through a "strainer." This substance may be separated from the milk by centrifugal force. The process is known as clarification, and the machine used 's known as a clarifier. The machine is built on precisely the same plan as a cream separator, and oftentimes the separator is used for the purpose.

Fig. 165. Where shrubs are needed.

Fig. 166. Where shrubs are added. Compare with Fig. 165.

PART III—SPECIAL TOPICS

CHAPTER XXXIV

THE HOME LOT

369. The Decoration of a Landscape with herbs, shrubs and trees has been called "picture-making out-of-doors." Whether we know it or not, all of us have a great appreciation of the beauty and grandeur of landscapes. We recognize that some landscapes are attractive, or that the surroundings of some homes look bleak. Again, there is the little cottage of the new-comer, simple though it may be, yet we say, "It's a nice place." Ask us why, and the answer is a very uncertain one. Why? It's because we fail to recognize the essentials of a good picture.

370. Studying Landscapes. Compare Fig. 165 with Fig. 166. Manifestly, one is more pleasing to the eye than the other, but why? Some shrubs have been added, it is true, but it is not the shrubs in themselves that are so noticeably pleasing. The shrubs cover up many of the harsh geometrical lines and make the landscape look more natural. Had the shrubs been placed in the open space the effect would not have been half so pleasing. The large open lawn gives an attractive setting for the trees farther on. A comparison of these two pictures teaches us the A, B, C of landscape art. In making

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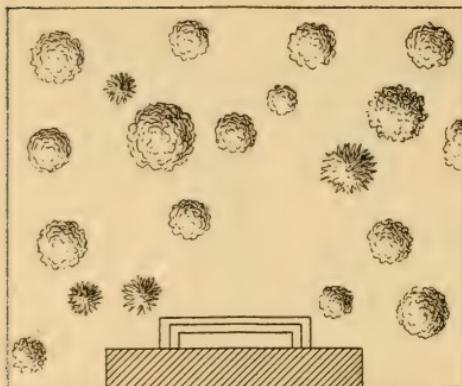
Fig. 167. A plan that brings the plants into prominence.

pictures on the landscape, whether around the home or the school house, we should

(A) Strive to avoid sharp, straight lines;

(B) Preserve open spaces;

(C) Plant in masses, and note how nature plants trees and shrubbery for instructive examples. (Figs. 167, 168.)

371. Rural Home Grounds should have such groupings of lofty trees and attractive shrubs that the sharp lines of houses, barns and fences shall be softened into a natural picture. The appearance of the home lot should suggest more than mere shelter for man and his useful animals. It should appear as though the house, barns and lots were built in what was naturally an attractive landscape. Open lawns and large trees are always pleasing. In the crowded city such features may, from necessity, be dispensed with, but, when the country house is set in a small yard, it impresses us immediately as showing too
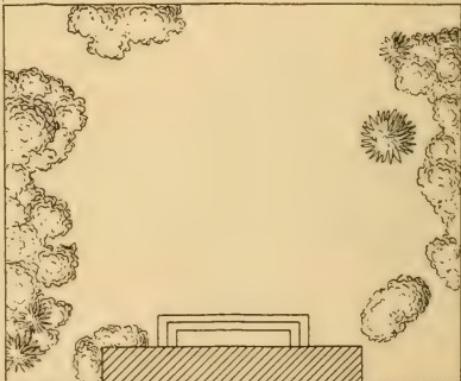
Fig. 168. A plan that makes a good picture, whether viewed from the house or the highway.
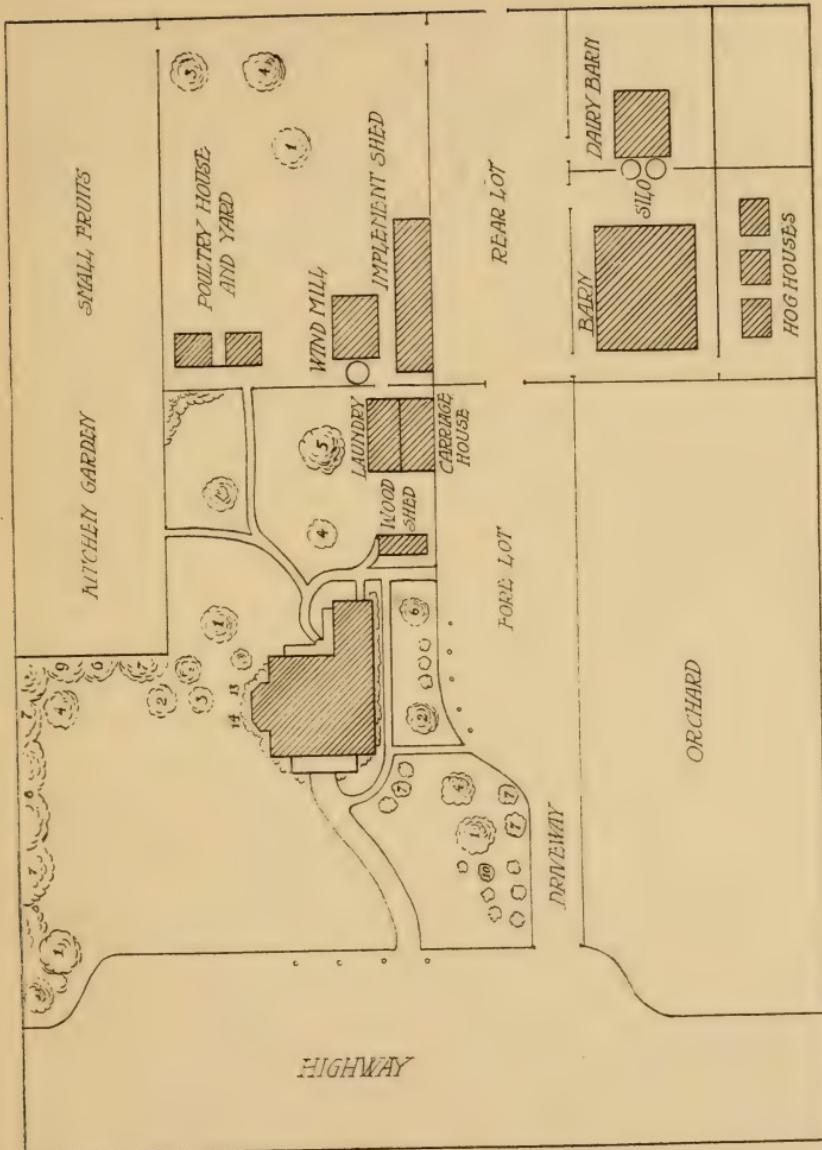
Fig. 169. A good plan for the arrangement and decoration of a farm-house, buildings and grounds.

great a contrast with the natural openness that is so characteristic of farm life.

372. Planning a Home Lot is a matter requiring much study. Along with the study of the view of the home site from within and without, we must cautiously plan for all the conveniences for the living of both man and beast. The location of the house, the barns, poultry houses, roads, gardens, orchards and fences should first be studied from the standpoint of convenience and healthfulness. When these features are planned, then we may study how to complete the picture and introduce those features that make a residence "home-like."

373. Completing the Picture. In placing the trees, shrubs and flower-beds, we should consider first the outlook from the house,—the view that we will see most often. Next we may consider the view from the highway. In both cases the openness of view should be preserved. In planting the trees and shrubs we are using them only as materials. They may make or mar the view, according to the way we arrange them. Fig. 169.

374. Locating the Plants. In making a plan, the grouping of the plants should be carefully worked out. For every plant to be used, we must know how it will look, and how much space is required when fully mature. After a satisfactory knowledge of the plants has been gained, we may mark the place for each on our plan (Fig. 169). The way the plants are grouped makes a great difference in the appearance of the place. Every attractive picture has some one central object. In making a picture on the landscape, the home, or the schoolhouse is to be made the central feature. As a picture is often marred by a poor frame, so may a landscape lose its attractiveness by improper use of plants.

375. Plants to Use. Landscape architects are also gardeners in that they must know the character of many kinds of plants and the conditions under which they succeed. In selecting trees and shrubs for home planting, it is important that sorts be used that succeed. Native wild plants should always be considered. By observing the plants that are grown on other persons' grounds, we may often learn of the good sorts and avoid undesirable varieties. In selecting the plants, it is always advisable to consult the local nurseryman.

375a. Make a list, using the names given in the nursery catalogues of all the different kinds of trees, shrubs, perennial and annual flowers that grow well in your locality. Mention the location in the community of one or more plants of each sort.

CHAPTER XXXV

SCHOOL GARDENS

376. The School is a place where many of our ideas and ideals are formed. It should be more than a place where we take short cuts to knowledge, that is, learning from teachers and books what others have found out by observation and investigation. Nature does not teach by words, pages or chapters. To understand nature's forces and how to control them, for our benefit, we must get close to her creatures.

377. The School Garden should be a place to learn what is true, beautiful and useful about plants, insects, soils, birds, sunshine and rain. We may do this by working with nature, by growing a small number of several kinds of plants and observing their needs as they grow from seed to fruitage. In outward appearance, school gardens do not differ from home gardens. All the common sorts of plants may be grown in a school garden, though we observe and study them more closely. Some plants must be cultivated one way, while others require different care. In a school garden we seek the explanation of the differences. If we grow a small number of plants and observe the progress of each separate plant, we will learn a great deal about how to care for a large crop. (See Frontispiece.)

378. Laying Out a School Garden. When a piece of ground has been secured it should be cut up into a number of small gardens—one for each student. A

diagram should be made showing all the walks and the location of each student's plot. Space should be left for walks between the gardens sufficient to allow access on all sides. The main walks may be five to eight feet wide, and the smaller walks only eighteen inches wide. A larger plot should be left for growing corn, pumpkins and other plants too large for the individual gardens. All students should take part in caring for the large plot. The laying out of the entire garden, and all questions about how it should be managed should be fully discussed by all students. Each student should make a plan and submit it to the teacher, who will select the best.

379. Individual Gardens. Every student—boy and girl—should have a small plot of ground on which they will begin work in the fall at the opening of school.

Each student should make a plan for his or her garden, covering the preparation of the ground, selecting the kinds of plants or seeds to be grown, and all other important features. If the teacher approves the plan, the work may be begun. If any changes are desired, the consent of the teacher should be secured before carrying them out. The students remain responsible for the success and appearance of their plots. Some gardens will be so fine that they will show the importance of care. No student should allow his or her garden to be pointed out as an example of what neglect will do.

380. Selecting Plants. In selecting plants for the garden, preference should be given to kinds that will mature during the school term. Some hardy sorts may be planted in the fall.

Many plants mature so quickly that two or more crops may be grown on the same land. The plan for the garden should show how and when the land will be

Dwarf Nasturtium	Petunia
Radish	Petunia
Radish	Zinnia
Radish	Zinnia
Lettuce	Ageratum
Lettuce	Nasturtium
Beans	Radish
Beans	Radish
Beets	Lettuce
Beets	Lettuce
Beans	Beets
Turnips	Beets
White oats	Beans
Red oats	Beans
Barley	Poppies
Wheat	Shirley Peppies Plant in fall

Left column brackets:
- Followed by tomatoes (Radish, Radish, Radish, Lettuce, Lettuce)
- Followed by beans or millet (Beans, Beans, Beets, Beets)
- Followed by cowpeas (White oats, Red oats, Barley, Wheat)

Right column brackets:
- Followed by tomatoes (Radish, Radish, Lettuce, Lettuce)
- Followed by turnips (Beets, Beets, Beans, Beans)

Fig. 170. Plan of a garden with vegetable and field crops.

Fig. 171. Plan of a garden with flowers and vegetables.

"As the roose in his radness is richest of floures."
—*Destruction of Troy*. Early English translation, 1670.

Oklahoma Agricultural and Mechanical College.
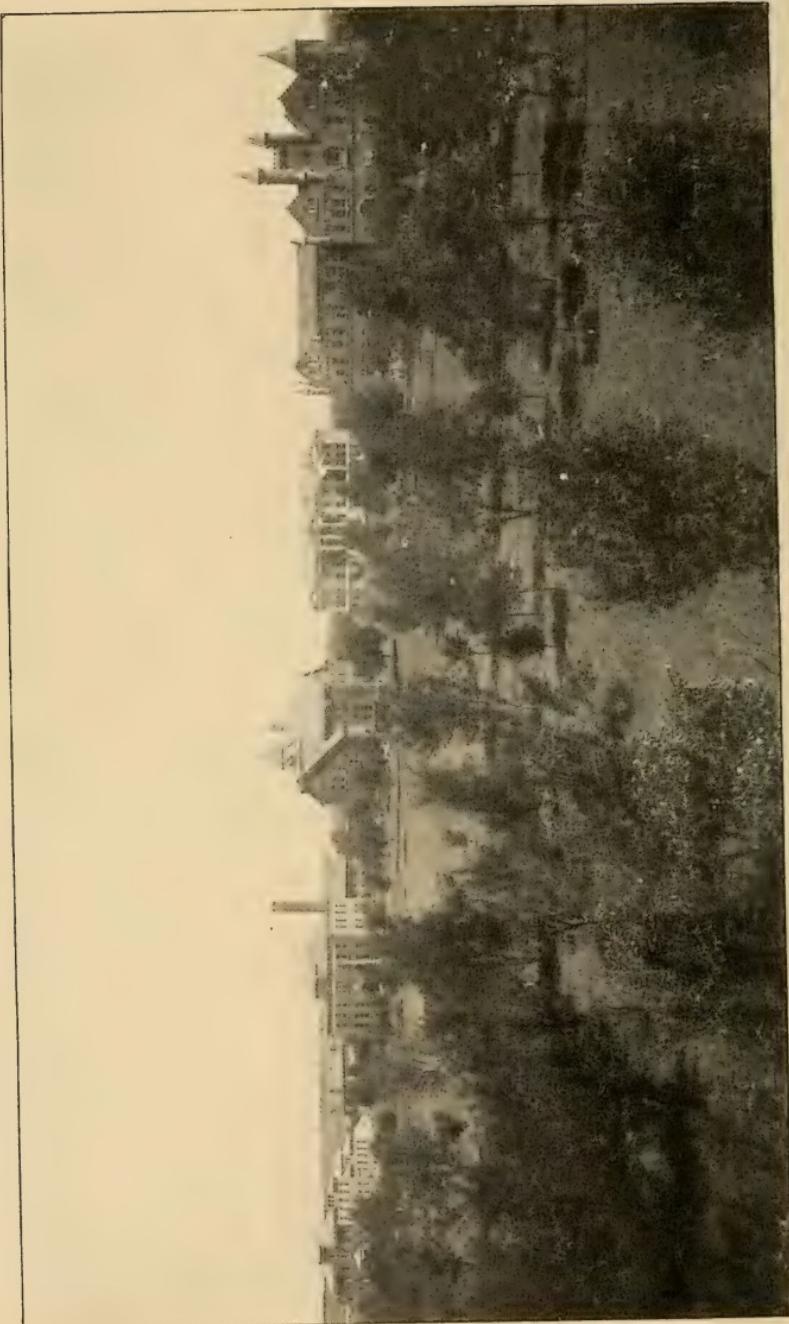
prepared, where each kind of plant will be in the garden. how and when each kind will be planted. Each student should strive to do well. Figs. 170 and 171.

381. The School Grounds should be made attractive by planting trees, shrubs, flowers and vines. Just as every one takes pride in the appearance of the home lot, so does the community feel a pride in keeping the school grounds in order. The school grounds should be kept in order by the pupils even during vacation.

CHAPTER XXXVI

FORESTRY

382. A Forest is a considerable piece of land covered with large trees. Forests are directly important to mankind as sources of fuel, lumber, heavy round timber, such as posts, piling, and telegraph poles; also, cooperage stock, tan bark, wood pulp for paper-making, rosin, cork and many other useful supplies. They are also important because of their good effect in regulating stream flow, preventing the erosion of the land and, probably, in modifying climate.

383. The Need of Forests was not fully recognized by the early settlers in timbered regions. The heavy timber was looked upon as an obstacle to rapid progress; but, in recent years, when railroads are at hand to haul the forest products wherever they may be needed, they are quite valuable. Before a piece of timbered land is destroyed, the probable value of the annual harvest of forest products should be carefully considered. America is now repeating the forestry experiences of European countries. The forests were first destroyed to make room for the fields, gardens and orchards, and, as the farming interest reduced the timbered areas, fuel and lumber supplies became more difficult to secure. Then the forest was looked upon as something of value that should not be destroyed. Where the natural covering of the hills and bottoms have been removed, the bad effects caused by the washing of the soil from the hills and the flooding of the valleys has been plainly seen.

384. Systematic Forestry teaches us to remove only the matured products, leaving the young timber to grow. France and many European countries have had to restore, though at great expense, the forest conditions to large areas that had been thoughtlessly destroyed. In many of the Old World countries no man is allowed to destroy a mature forest tree without permission of a forest official, and this is often given only when another is started to take its place. Such restrictions seem needlessly severe to us, but is it improbable that, some day, we may find some such restriction necessary for the public good?

385. The Exhaustion of Our Forest Resources is now going on at a rapid rate. Our forested areas are being rapidly reduced. Fig. 172 illustrates the present difference between the use of forest products and the rate of increase by growth. The eastern states have long since all but exhausted their natural forests. They once secured the needed supplies of lumber from the virgin forests of the north central states, but today those areas are almost exhausted and the large lumber supplies

Fig. 172. Excess of annual cut over annual forest growth.

are now furnished by the northwestern and southern states.

386. Conserving Our Forest Resources is a national need. In former times the lumberman cut everything. The young timber was needlessly destroyed. Now, however, they have realized the value of the small

seedlings and saplings, and seek to protect them from forest fires and the grazing of stock. All the conditions that favor the growth of the young trees are carefully considered by the modern forester.

387. Our Forest Reserves. Our government, observing the great hardships resulting from an insufficient supply of forest products in the Old World, and how quickly the forests of the East and middle states have been reduced, has set aside large tracts of timbered regions in the western states as National Forest Reserves. These reserves form but a small part of our present forest resources; but, taken with the privately owned forests, are sufficient to supply our needs if properly used. Forestry plantings have been maintained in older countries for long periods and experience has shown that such plantings yield an annual revenue equal to four to eight dollars per acre.

388. The Forest Service of the United States Department of Agriculture, and the Forestry Commissioners provided for in many states. study the problems of forest management and issue bulletins of information for the instruction of all who have land suitable for timber-growing.

389. The Farm Wood-Lot. In many sections the waste lowland and the hill land may be planted to trees to supply fuel, poles and the many special timbers needed on every farm. In many cases such lands have been made to return to the farm products equal in value to the returns of the regular field crops. The value of a wood-lot will depend much upon the care, nature of the soil. and the kinds of trees planted. Of course it takes some years before the first harvest can be made; but this may be greatly shortened by planting thick and

cutting out the less desirable forms as the growth thickens. Varieties for wood-lot planting should be selected to suit the locality. Hardy catalpa, black locust, black walnut, honey locust, Bois d'Arc, or Osage orange, mulberries, and many other sorts, have proven to be well suited to many sections of the South and West. Not every wood-lot has turned out a success;
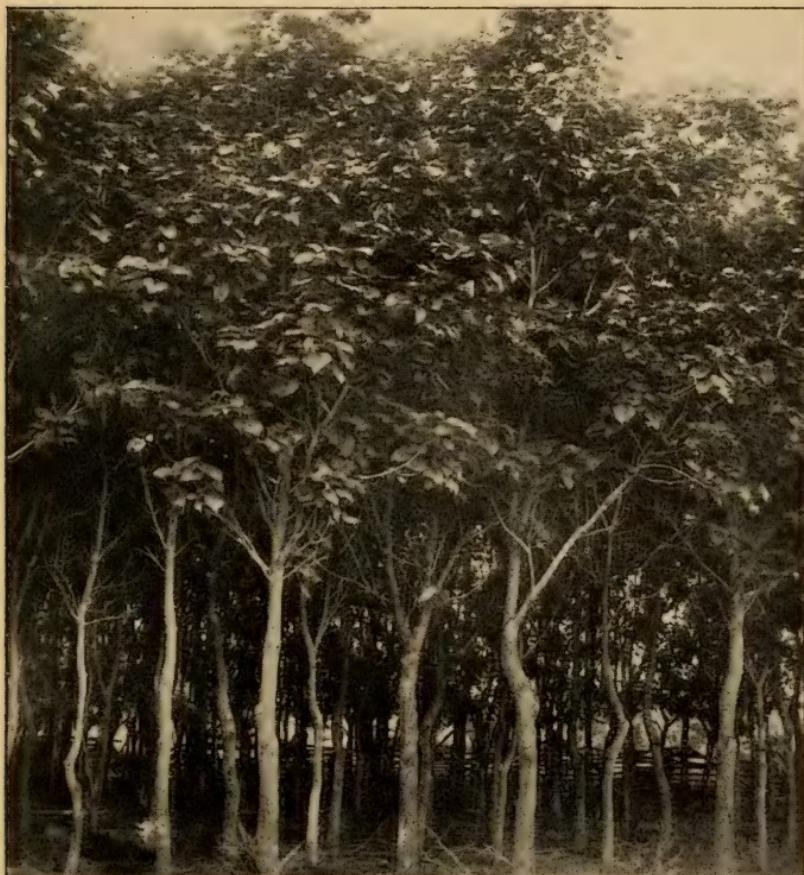
Fig. 173. A catalpa plantation. Every farm should have a wood lot. From Year Book, United States Department of Agriculture, 1899.

but a larger number have. Many of the failures were due to neglect or to the selection of species unsuited to the conditions.

389a. A farmer planted a large acreage of bottom land to hardy catalpas, in rows six feet apart and four feet apart in the row. At the end of ten years he found the books showed the following items: Cost of rent on land for ten years, seedlings, planting, cultivating, trimming, marketing, etc., $56. Value of stakes and small posts secured, early thinning, $63. Stock on hand: 678 posts, first class, 10 cents each; 712 posts, second class, 7 cents each; 616 posts, third class, 4 cents each. What was the approximate value per acre per year of the crop?

390. Windbreaks. In open regions, windbreaks, formed by growing shrubs and trees, have been found to be quite beneficial because of the protection they give to growing crops and orchards, or to stock. Windbreaks reduce the evaporation from the soil and from the plants themselves. They often prevent the drifting of the soil in open, sandy regions. They also protect stock from cold winds in winter and hot winds in summer. In regions that most need windbreaks, it is most difficult to get the trees to grow. The plan that has proven most satisfactory is to make plantings of arborvitæ, locusts, Osage orange, red cedar, blackberries, green ash, or other species in wide rows and cultivate the trees until they become thoroughly established.

FARM MACHINERY

By PROF. J. B. DAVIDSON, Professor of Agricultural Engineering,
Iowa State College

391. Progress in Agriculture owes much to the intro-
duction of machine methods for doing hand labor. When
the savage began to plant seeds with a sharp stick in-
stead of depending on wild nature, the idea was certainly
a progressive one. When he learned that destroying the
weeds that came up with those seeds would add to the
quantity and the certainty of the harvest, he ceased to
be a savage. Still again, when he learned to prepare
the ground and cultivate his crops, civilization was
well established. "Civilization begins and ends with the
plow," and yet the plow remained a crude wooden tool
until within comparatively recent times.

392. Tillage Tools were not noticeably improved
until chemists and botanists began to study the soil and
formed a theory about the relation of the soil to the
plant. Machines are not invented until the need for
them is recognized. The ideas about the relation of the
plant to the soil given in modern books would have
been wondrous strange to our great-grandparents.
McMaster[*] tells us that "The Massachusetts farmer
who witnessed the Revolution, plowed his land with a
wooden bull-plow, sowed his grain broadcast, and, when
it was ripe, cut it with a scythe and thrashed it out on
his barn floor with a flail." These implements were

[*]History of the People of the United States.

similar to the ones used by the Egyptians three thousand years before. It is worthy of note that many of the greatest of the early Americans were interested in the development of the plow, the fundamental implement of tillage. Thomas Jefferson and Daniel Webster planned plows and had them constructed, which were improvements over preceding types. In 1797, Charles Newbold introduced the iron plow, but it is recorded that the farmers of that time refused to use it, claiming that so much iron drawn through the soil poisoned the
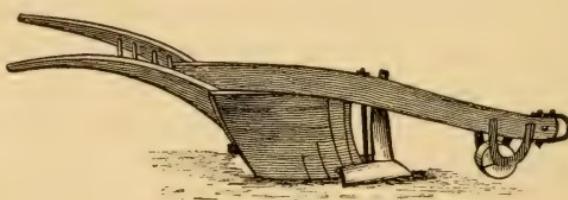
Fig. 174. Webster's plow.

land and increased the growth of weeds. This latter superstition delayed the general acceptance of improved plows for many years. The use of iron and steel plows did not become general until about 1830. Many improvements were made in the construction and form of the points and mold-boards, adapting them to various kinds of soils. The modern plow is familiar to all. The recent types of sulky plows enable the plowman to ride in a comfortable seat, and, when properly adjusted, so that the pressure due to the raising and turning of the furrow slice have no heavier draft than the walking plow. The single-shovel cultivator has given way to the double-shovel implement, and this, in turn, to the straddle-row cultivator, and, in many sections, the two-row cultivator is finding favor.

393. Harvesting Machinery. Perhaps no line of development has assisted agriculture so much as machine harvesting. The grass hook and the scythe were long in use. When a Scotchman put fingers to the scythe, forming the cradle, it was heralded as a great invention because it enabled one man to do the work of several equipped with the older implements. Obed Hussey and Cyrus H. McCormick* stand out prominently in the development of the reaper, which was later improved by many others, among whom Palmer, Williams, Marsh Brothers, Spaulding and Appleby should be mentioned, leading up to the self-binder in 1878. It appears marvelous to find that there has taken place within sixty years—within the life of a single man—the universal introduction of machines which

Fig. 175. C. H. McCormick.

are so efficient and still require the guidance of but one man to do the work of many.

394. Farm Machinery. The general introduction of specialized farm machines,—implements too complex

*Cyrus H. McCormick was born in Rockbridge county, Virginia, in 1809. His father had constructed a reaping machine, though his efforts, like those of many others along the same line, were not successful. Young Cyrus had watched his father's experiments and cherished the thought that some day he might solve the difficult problem. He abandoned the principles that had formed the underlying features of his father's machine. The elder McCormick did not approve of the young man's plans, but he put no obstacles in his way, and offered him the facilities of his little blacksmith shop to build his first machine. Young McCormick completed his first reaper in time to give it a trial in the harvest of 1831, and it worked successfully that year.

R

to be called tools,—has made the modern farmer a
mechanic. Modern haying implements, consisting of
mowers, rakes, hay-loaders, stackers and presses, have
greatly reduced the hand work in hay-making. It has
been estimated that the farmer of 1850 spent eleven
hours in cutting and storing a ton of hay, while, under
modern methods, the time has been reduced to one hour
and thirty-nine minutes. There are machines for every
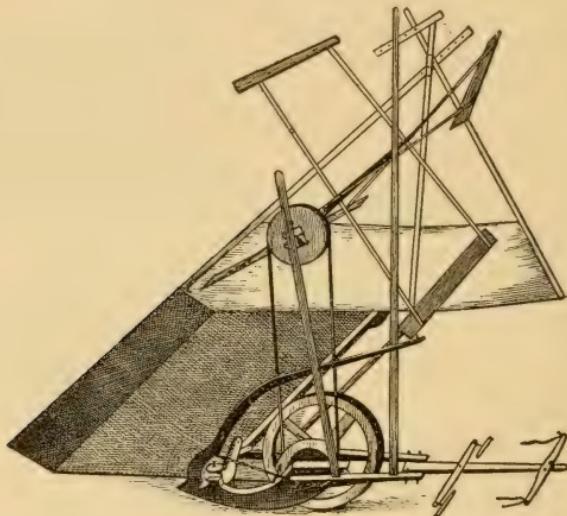
Fig. 176. McCormick reaping machine, 1834.

class of farm work: Threshing-machines for threshing
grain; shellers, for shelling corn from the cob; huskers
and shredders, for removing the ears from the corn-
stalk and converting the latter into palatable food for
farm animals, and many others. This is true to such an
extent that large farms have nearly as much invested
in machinery as some factories. Many forms of machinery
used on the farm require considerable power. Wind-
mills, gasoline engines, and even steam engines, are not

infrequently in regular use for pumping water, grinding grain, separating milk and other special operations. These motors increase the capacity of the farm worker by enabling him to use and direct more power, resulting in more economical production. Fig. 177.

395. Power Versus Hand Labor. The change from hand tools to implements and special machinery has lead to the use of more power for each worker, and the
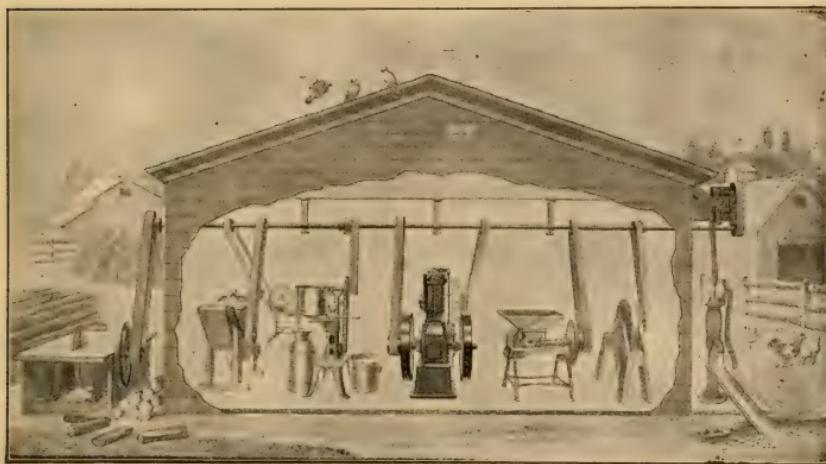
Fig. 177. A suggestion for the use of power on the farm. From an agricultural implement catalogue.

amount is governed somewhat by the ability of the worker. Man, when working alone, is able to develop only about one-eighth horse power. When he uses one horse, his capacity to work is increased eightfold, and if two horses are used, sixteenfold. The American farmer is not content to drive his brain with a one-horse power when two, three or four may be used to advantage. This demand for more power has stimulated the breeding of larger horses for draft purposes.

396. Care of Machinery. The operation of many

forms of farm machinery often taxes the mechanical skill of the average worker. Much loss results from the neglect to repair agricultural machines promptly and systematically. Many machines are discarded which would be almost as good as new if the broken parts were replaced. Costly agricultural machines should be kept under shelter when not in actual use to lengthen their period of usefulness.

397. The Influence of Agricultural Machinery on the quantity and quality of farm productions has brought many changes. The year 1850 has been mentioned as marking the transition from the use of implements for hand-production to those for machine-production. The increase in production per farm worker under modern methods is most marked. The Roman farmer in the time of Columella spent four and six-tenths days in growing a bushel of wheat. It is stated in the Thirteenth Annual Report of the United States Department of Labor that the American farmer spent three hours in 1830, under hand methods, in producing a bushel of wheat, at a cost of 17.7 cents, while now the same result is secured in nine minutes at a cost of 3.5 cents. In 1800, 97 per cent of our people were living on farms, or in small towns, depending upon agriculture for food; yet, with all this army of workers, the country raised only five and five-tenths bushels of wheat per person. In 1900, while approximately only one-third of the population lived on farms, the production of wheat was ten bushels per capita, one-half of which was in excess of our needs.

398. Other Changes in Farm Conditions have been made, at least in part, as a result of the change from hand methods to machine methods of production. An

old method of threshing grain was by the treading of animals, but bread made from wheat threshed in this manner would not be salable today. Women are no longer required to do heavy field work as they did at one time. The working day has fewer hours and the wages of the farm-worker has increased many fold. "All intelligent expert observation," says Dodge, "declares it beneficial. It has relieved the laborer of much drudgery; made his work lighter and his hours of service shorter; stimulated his mental faculties; given equilibrium of effort to mind and body; made the laborer a more efficient worker, a broader man and a better citizen."

APPENDIX A

BOOKS ON AGRICULTURE

A. Primarily for Teachers—

The Nature Study Idea, Bailey. (Doubleday, Page & Co.)

Special Method in Elementary Science, McMurray. (Macmillan.)

Principles of Agriculture, Bailey. (Macmillan.)

B. For Teachers and Patrons—

The Farmstead, Roberts. (Macmillan.)

Rural Wealth and Welfare, Fairchild. (Macmillan.)

C. Supplementary Texts on Agriculture—

The First Book of Farming, Goodrich. (Doubleday, Page & Co.)

Principles of Plant Culture, Goff. (University Coöperative Company, Madison, Wis.)

D. Special Treatises and Books for Reference and General Reading—

The Great World's Farm, Gaye. (Greely & Co.)

Plants and Animals Under Domestication, Darwin. (D. Appleton.)

The Soil, King. (Macmillan.)

Art Out-of-Doors, Van Rensselaer. (Scribner.)

How to Plant the Home Grounds, Parsons.

Disease in Plants, Ward. (Macmillan.)

The Spraying of Plants, Loderman. (Macmillan.)

Principles of Fruit Growing, Bailey. (Macmillan.)

The Nursery Book, Bailey. (Macmillan.)

The Pruning Book, Bailey. (Macmillan.)

The Care of Animals, Mayo. (Macmillan.)

Fertilizers, Voorhees. (Macmillan.)

Breeds of Live Stock, Craig.

Elements of the Theory and Practice of Cookery,

The Book of Alfalfa, Corburn. (Orange Judd Co.)

Farm Machinery, Davidson and Chase. (Orange Judd Co.)

APPENDIX B

INSECTICIDES AND FUNGICIDES

Bordeaux Mixture. This is the fungicide used everywhere to reduce damage to fruits and vegetables caused by fungi. The proportions in which the substances are mixed are but rarely varied from the following:

Copper Sulfate, or Bluestone ....∴ 4 pounds
Fresh lime .... 4 "
Add water to make...................about 50 gallons

In preparing, use two half-barrels, one for copper sulfate and one for lime. Fig. 178. The copper sulfate should be pulverized and put in a coarse burlap sack and suspended in water until dissolved. Use wooden vessels only for copper sulfate. The fresh lime should be dissolved in another vessel, using only a small amount of water at first, adding more as the slaking progresses. Care should be taken to see that the lime is stirred into a very thin batter, free from even small lumps.

Fig. 178. Making Bordeaux mixture.

It is advisable to strain through a burlap sack, or a copper strainer with eighteen or twenty meshes to the inch. Dilute the milk of lime and the solution of copper sulfate up to about twenty-five gallons and mix. Do not

attempt to pour the milk of lime into the copper sulfate,
or the reverse, but pour together in equal quantities
into a third vessel.

Success in preparing Bordeaux mixture of uniform
color and consistency will depend on the pureness
of the substances and the manner of mixing. When
properly prepared it has a sky-blue color. If the lime
is not fresh, a greenish color sometimes results, which
indicates that more lime is needed. It is advisable to
have an excess of lime. Where plants with delicate
foliage, like the peach, are to be sprayed, three times
as much lime as copper sulfate is used.

Insecticides With Bordeaux Mixture. It is often de-
sirable to apply an insecticide at the same time a fungi-
cide is applied, in order to obviate the necessity of two
sprayings. This is often done when internal poisons, like
Paris Green, London Purple, or Arsenate of Lead, are
used. They may be added to the Bordeaux Mixture at the
rate of one-fourth pound to fifty gallons of Bordeaux.

Lime and Sulfur Preparations are much used to
destroy scale insects. They act both as a fungicide and
an insecticide, though their use is advisable only during
the dormant season. The preparations in common use
vary somewhat in detail. The following is often used:

Fresh lime ....15 to 30 pounds
Flowers of sulfur............................15   "
Common salt..............................10   "
Water to make ....50 gallons

When the lime is perfectly fresh, the smaller quantity
named above will answer.

To make the preparation, proceed as follows: Slake
the lime with hot water, adding the water slowly until
about ten gallons are used. Then add the sulfur and

salt and stir until thoroughly mixed. Boil this mixture
for from forty-five to sixty minutes to thoroughly
dissolve the sulfur. The sulfur dissolves most easily
in a thin milky solution of lime, and, for this reason,
no more water is used in dissolving the sulfur than is
necessary to keep the mixture from becoming pasty.
When the sulfur is thoroughly dissolved, pass the solu-
tion through a strainer and dilute to the desired con-
centration with hot water. The mixture should be pre-
pared just as needed, and applied while still warm.

Kerosene Preparations. Kerosene oil is an external
irritant and is very effective in killing insects. It can
not be applied to plants, however, in its crude form,
without producing serious injury. Resort is had, there-
fore, to various substances to dilute and carry the oil,
such as soap-suds, milk, milk of lime, or even water
alone, automatically mixed with the water in forming
the spray. Kerosene preparations
should be applied to plants with great
caution. They are very efficient in
fighting certain injurious insects, but
if not properly applied, serious injury
to the plant may result.

Fig. 179. Hand bucket spray pump. A longer hose than that shown is needed for convenient using.

Kerosene Emulsion. Dissolve one
pound of Naphtha soap in two and
one-half gallons of water. Then add
two and one-half gallons of kerosene
to the solution and thoroughly mix by
pumping the entire mixture through
a bucket sprayer. Fig. 179. Now di-
lute to from twenty to thirty gallons
as desired. Apply while fresh. Used for scale and other
sucking insects.

Paris Green is a standard poison for all insects that bite and swallow their food. It is heavy and, therefore, requires constant agitation to keep suspended in the spraying preparation. Paris Green is used at rate of about four ounces to fifty gallons of water. It is advisable to add some lime to the mixture to prevent injury to the foliage. It should be first worked into a paste before adding to a large quantity of water, whether used singly or in combination with Bordeaux Mixture.

Arsenate of Lead. This is often preferred to Paris green because it is lighter, remains in suspension longer, and adheres to the foliage better. It is white in color and can be readily seen. Another important advantage claimed for Arsenate of Lead is that it is less liable to injure tender foliage. In its preparation use:

Arsenate of soda............................ 4 ounces
Acetate of lead 11   "
Water....................................16 gallons

Dissolve the first two separately in a small amount of water and then mix and add the full quantity of water. It may be purchased, prepared ready for use, at seed stores.

Dust Applications of Insecticides are sometimes advisable. Special machines are on the market for applying both insecticides and fungicides in the form of dust. Dust applications have not been found so uniformly satisfactory as the liquid applications.

Spraying Domestic Animals with poisons is sometimes recommended to kill insects, ticks and other parasites. Various preparations of oils and arsenical preparations are used. London Purple, dusted on the perches, nest and bodies of poultry, is a very satisfactory way to destroy mites on poultry. If applied regularly, it becomes a preventive.

APPENDIX C

Composition of American Feeding Stuffs

	Pounds per hundred					
	Water	Ash	Protein	Fiber	Nitrogen-free extract	Fat
Green Feeds.						
Corn fodder, whole plant	73.4	1.5	2.0	6.7	15.5	0.9
Kaffir corn fodder	73.0	2.0	2.3	6.9	15.1	0.7
Sorghum fodder...............	69.4	1.8	1.6	8.8	16.8	1.6
Kentucky Blue grass	65.1	2.8	4.1	9.1	17.6	1.3
Johnson grass................						
Alfalfa	71.8	2.7	4.8	7.4	12.3	1.0
Cowpea	83.6	1.7	2.4	4.8	7.1	0.4
Peanut vines						
Dry Hay and Fodders.						
Corn fodder, entire plant	42.2	2.7	4.5	14.3	34.7	1.6
Corn fodder, leaves only.......	30.0	5.5	6.0	21.4	35.7	1.4
Corn husks from ears	50.9	1.8	2.5	15.8	28.3	0.7
Kaffir corn stover	19.2	8.0	4.8	26.8	30.6	1.6
Hay from						
Oats....................	16.0	6.1	7.4	27.2	40.6	2.7
Timothy	13.2	4.4	5.9	29.0	45.0	2.5
Prairie grass	7.7	6.4	3.8	34.8	45.7	1.5
Johnson grass.............	9.9	5.7	12.8	29.1	39.8	2.7
Millet....................	8.8	10.1	11.1	32.1	34.8	2.9
Mixed grasses.............	15.3	5.5	7.4	27.2	42.1	2.5
Red clover	20.8	6.6	12.4	21.9	33.8	4.5
Alfalfa, minimum	4.6	3.1	10.2	14.0	35.1	1.1
Alfalfa, maximum	16.0	10.4	20.3	33.0	53.6	3.8
Alfalfa, average	8.4	7.4	14.3	25.0	42.7	2.2
Cowpea	10.7	7.5	16.6	20.1	42.2	2.9
Peanut vines, without nuts ...	7.6	10.8	10.7	23.6	42.7	4.6
Oat straw , ...	9.2	5.1	4.0	37.0	42.4	2.3
Wheat straw................	9.6	4.2	3.4	38.1	43.4	1.8
Roots and Tubers.						
Sweet Potatoes	71.1	1.0	1.5	1.3	24.7	0.4
Irish potatoes...............	78.9	1.0	2.1	0.6	17.3	0.1
Sugar beets.................	86.7	0.8	1.5	0.9	9.9	0.1
Turnips	90.6	0.8	1.3	1.2	5.9	0.2
Carrots	88.6	1.0	1.1	1.3	7.6	0.4

APPENDIX D

Per Cent of Digestible Nutrients in Stock Feeds

	Animal	Digestion coefficients						
		Dry matter	Organic matter	Ash	Protein	Fiber	Nitrogen-free extract	Fat
		%	%	%	%	%	%	%
Timothy, green	Steers	63.5	65.6	32.2	48.1	55.6	65.7	53.1
Timothy, green	Horse	43.5	44.1	34.1	21.2	42.6	47.3	47.3
Timothy, hay, dry	......	53.4	54.5	30.3	45.1	47.1	60.4	51.9
Mixed hay...............	......	....	....	....	48.0	48.0	57.0	50.0
Oat straw	......	....	....	....	38.-	58.0	53.0	38.0
Oat straw	......	50.3	52.0	....	....	57.6	53.2	38.0
Johnson grass, dry........	......	56.5	58.3	30.5	41.4	65.7	56.9	38.4
Corn fodder, leaves	......	59.8	63.6	26.8	48.4	67.5	63.0	59.9
Corn shucks	......	72.0	74.2	16.0	29.5	79.5	75.0	32.5
Alfalfa hay	......	58.9	60.7	39.5	72.0	46.0	69.2	51.0
Corn, unground	Horse	74.4	75.3	26.3	57.8	....	88.2	47.7
Corn meal	Horse	88.4	....	....	75.6	....	95.7	73.1
Corn, unground	Swine	82.5	83.4	....	68.7	38.3	88.8	45.6
Corn, ground	Swine	89.5	91.2	....	86.1	29.4	94.2	81.7
Corn meal	Sheep	89.6	90.7	49.5	76.9	....	95.3	98.1
Corn meal	Cows	84.6	82.8	....	58.3	....	87.1	91.9
Oats, unground	Horse	72.4	74.1	33.1	86.1	31.1	79.4	82.4
Oats, ground	Horse	75.7	77.7	29.2	82.4	14.4	86.3	79.9
Wheat bran	Swine	65.8	....	....	75.1	33.0	65.5	71.8
Wheat bran	Sheep	58.7	61.6	17.3	70.2	16.1	67.2	72.1
Wheat bran	Steers	67.3	68.6	47.1	82.3	25.1	74.6	54.7
Cotton-seed hulls.........	Cow	35.9	36.2	27.1	24.6	27.4	40.3	80.6
Cotton-seed hulls.........	Goats	38.6	39.8	20.9	....	45.2	37.4	87.1
Cotton-seed meal.........	Goat	65.9	69.5	19.8	86.8	46.8	43.8	92.4
Cotton-seed meal.........	Cow	77.9	80.0	35.0	89.8	....	68.1	89.4
Cotton seed, raw	......	66.1	65.8	43.3	67.8	75.5	49.6	87.1
Cotton seed, roasted	......	55.9	56.8	....	46.9	65.9	51.4	71.7
Potatoes, raw............	......	75.7	77.0	....	44.7	....	90.4	13.0
Potatoes, boiled..........	......	80.1	81.2	....	43.4	....	92.1	
Sugar beets..............	......	94.5	98.7	31.9	91.3	100.0	99.7	49.9
Turnips	......	92.8	96.1	58.6	89.7	100.0	96.5	87.5

APPENDIX E

Average Digestible Nutrients and Fertilizing Constituents in Stock Feeds

	Dry matter in 100 pounds	Digestible nutrients in 100 pounds				Fertilizing constituents in 100 pounds		
		Protein	Carbo-hydrate	Fat	Fuel value	Nitrogen	Phosphoric acid	Potash
GREEN FEEDS.								
Corn fodder, entire plant	20.7	1.10	12.08	0.37	26.076	0.30	0.15	0.30
Kaffir corn fodder	27.0	0.87	13.80	0.43	29.101			
Sorghum fodder	30.6	0.70	17.60	0.20	.....	0.30	0.09	0.25
Johnson grass	....	.....	.....	.....	.....	....	....	....
Red clover	29.2	3.07	14.82	0.69	36.187	0.54	0.15	0.40
Cowpea vines	16.4	1.68	8.08	0.25	19.209	0.27	0.10	0.30
Alfalfa	28.2	3.89	11.20	0.41	29.798			
Peanut vines	....	.....	.....	.....	.....	....	....	....
DRY FODDERS AND HAY								
Corn stover	59.5	1.98	32.16	0.57	67.766	1.10	0.29	1.40
Kaffir corn stover	80.8	1.82	41.42	0.98	84.562			
Sorghum stover	....	.....	.....	.....	.....	....	....	....
Johnson grass	....	.....	.....	.....	.....	....	....	....
Red clover	84.7	7.38	38.15	1.81	92.324	0.54	0.15	0.40
Cowpea vine hay	89.3	10.79	38.40	1.54	97.865	2.66	0.52	1.47
Alfalfa hay	91.6	10.58	37.33	1.38	94.936			
Peanut vine hay	....	.....	.....	.....	.....	....	....	....
Wheat straw	90.4	0.37	36.30	0.40	69.894	0.60	0.22	0.63
Oat straw	90.8	1.20	38.64	0.76	77.310	0.46	0.28	1.77
Hay, mixed grasses	87.1	5.90	40.90	1.20	93.925	1.40	0.27	1.55
GRAINS AND SEEDS.								
Corn, whole grain	89.1	8.00	65.90	4.60	157.237	1.58	0.57	0.37
Corn meal	89.1							
Kaffir corn	87.5	5.78	53.58	1.33	116.022			
Oats	89.0	9.25	48.34	4.18	124.757	1.65	0.69	0.48
Wheat, all varieties	89.5	10.23	69.21	1.68	154.848			
Wheat bran	88.1	12.20	39.20	2.70	111.138	2.67	2.89	1.61
Wheat middlings	87.9	12.80	53.00	3.40	136.996	2.63	0.95	0.63
Wheat shorts	88.2	12.22	49.98	3.88	131.855			
Cotton seed	89.7	11.08	33.13	18.44	160.047			
Cotton-seed meal	91.5	38.10	16.00	12.60	152.653	6.90	3.00	1.50
Cotton-seed hulls	89.5	0.30	32.90	1.70	69.839	0.69	0.25	1.02
ROOT CROPS.								
Irish potatoes	21.1	1.36	16.43	.....	33.089	0.24	0.08	0.37
Turnips	9.5	0.81	6.46	0.11	13.986	0.19	0.09	0.34
Carrots	11.4	0.81	7.83	0.22	16.999			
Beets	13.0	1.21	8.84	0.05	18.904			

Composition of American Feeding Stuffs, continued

	Pounds per hundred					
	Water	Ash	Protein	Fiber	Nitrogen-free extract	Fat
Grains and Seeds.						
Corn, minimum	6.2	1.0	7.5	0.9	65.9	3.1
Corn, maximum...............	19.4	2.6	11.8	4.8	75.7	7.5
Corn, average................	10.6	1.5	10.3	2.2	70.4	5.0
Kaffir corn	12.5	1.3	10.9	1.9	70.5	2.9
Barley	10.9	2.4	12.4	2.7	69.8	1.8
Oats.......................	11.0	3.0	11.8	9.5	59.7	5.0
Sunflower seed	8.6	2.6	16.3	29.9	21.4	21.2
Cotton-seed, whole	5.8	2.9	14.5	10.9	17.3	15.3
Cotton seed, hulls	11.1	2.8	4.2	46.3	33.4	2.2
Cotton-seed meal.............	8.2	7.8	42.3	5.6	23.6	13.1
Peanut hulls.................	9.0	3.4	6.6	64.3	15.1	1.6
Peanut, kernel only...........	7.5	2.4	27.9	7.0	15.6	39.6
Cowpeas	11.9	3.4	23.5	3.8	55.7	1.7
By-Products of Mills.						
Corncob....................	10.7	1.4	2.4	30.1	54.9	0.5
Gem from corn	10.7	4.0	9.8	4.1	64.0	7.4
Gem meal from corn..........	8.1	1.3	11.1	9.9	62.5	7.1
Wheat bran	11.9	5.8	15.4	9.0	53.9	4.0
Wheat middlings	12.1	3.3	15.6	4.6	60.4	4.0
Wheat shorts	11.8	4.6	14.9	7.4	56.8	4.5
Rice bran	9.7	10.0	12.1	49.5	49.9	8.8
Dairy Products.						
Whole milk.................	87.2	0.7	3.6	....	4.9	3.7
Skim milk, gravity creaming ...	99.4	0.7	3.3	....	4.7	0.9
Skim milk, separator	90.6	0.7	3.2	....	5.2	0.3
Buttermilk	91.0	0.7	3.0	....	4.8	0.5
Whey......................	93.8	0.4	0.6	....	5.1	0.1
By-Products, Packery.						
Dried blood	92.0	....	87.0	....	....	....
Meat scraps	78.0	17.39	49.72	....	....	18.51
Tankage	92.0	....	60.0	....	....	8.0

APPENDIX F

Approximate requirements of nutrients for a day's feeding per 1,000 pounds live weight

	Dry matter	Digestible nutrients			Fuel value	Nutritive ratio
		Protein	Carbon hydrate	Fat		
	Lbs.	Lbs.	Lbs.	Lbs.	Calories	
Oxen—						
At rest in stall	18	0.7	8.0	0.1	16,600	1:11.6
At light work	22	1.4	10.0	0.3	22,500	1:9.3
At heavy work.................	28	2.8	13.0	0.8	32,755	1:5.0
Dairy cattle, in milk—						
Giving 11 pounds milk a day	25	1.6	10.0	0.3	22,850	1:6.8
Giving 16.5 pounds milk a day....	27	2.0	11.0	0.4	25,850	1:5.4
Giving 22 pounds milk a day	29	2.5	13.0	0.5	30,950	1:5.6
Giving 27.5 pounds milk a day....	32	3.3	13.0	0.8	33,700	1:4.5
Cattle, growing age—						
About 150 lbs., 2 to 3 months ...	23	4.0	13.0	2.0	40,050	1:3.4
About 300 lbs., 3 to 6 months	24	3.0	12.0	1.0	33,600	1:4.7
About 500 lbs., 6 to 12 months ...	27	2.0	12.5	0.5	29,100	1:6.8
About 700 lbs., 12 to 18 months ..	26	1.8	12.5	0.4	28,300	1:7.5
About 900 lbs., 18 to 24 months ..	26	1.5	12.0	0.3	26,350	1:8.4
Sheep—						
Heavy fleeced breeds	23	1.5	12.0	0.3	26,400	1:8.5
Ewes, with lambs	25	2.9	15.0	0.5	35,400	1:5.5
Growing, wool breeds —						
60 to 75 lbs., 4 to 8 months	25	3.2	14.0	0.7	35,500	1:4.9
80 to 90 lbs., 8 to 15 months ...	23	2.0	11.3	0.4	26,000	1:6.1
Growing, mutton breeds—						
60 to 80 lbs., 4 to 8 months	26	4.0	15.0	0.7	38,000	1:4.1
100 to 150 lbs., 8 to 15 months .	23	2.2	13.0	0.5	30,000	1:6.4
Swine—						
Growing, breeding stock—						
50 to 100 lbs., 2 to 5 months ...	40	6.5	25.5	0.9	60,000	1:4.0
120 to 200 lbs., 5 to 8 months ..	30	3.8	20.0	0.4	45,000	1:5.5
200 to 250 lbs., 8 to 12 months .	26	3.0	17.0	0.2	35,000	1:5.8
Growing, fattening—						
About 50 lbs., 2 to 3 months ...	44	7.6	28.0	1.0	70,000	1:3.7
About 100 lbs., 3 to 5 months ..	35	5.0	23.0	0.8	55,650	1:4.7
About 150 lbs., 5 to 6 months ..	33	4.3	22.3	0.6	52,000	1:5.4
About 200 lbs., 6 to 8 months ..	30	3.6	20.5	0.4	46,500	1:5.9
About 275 lbs., 9 to 12 months .	26	3.0	18.3	0.3	40,900	1:6.3

APPENDIX G

Approximate requirements of nutrients per day per head

	Age	Average live weight per head	Digestible nutrients			Fuel value	Nutritive ratio
			Protein	Carbon-hydrate	Fat		
	Months	Lbs.	Lbs.	Lbs.	Lbs.	Calories	
Growing cattle	2–3	150	0.60	2.10	0.300	6,288	1:4.6
	3–6	300	1.00	4.10	0.300	10,752	1:4.7
	6–12	500	1.30	6.80	0.300	16,332	1:5.3
	12–18	700	1.40	9.10	0.280	30,712	1:6.8
	18–24	850	1.40	10.30	0.260	22,859	1:7.7
Growing sheep	5–6	56	0.18	0.87	0.045	2,143	1:5.4
	6–8	67	0.17	0.85	0.040	2,066	1:5.4
	8–11	75	0.16	0.85	0.037	2,035	1:6.0
	11–15	82	0.14	0.89	.032	2,050	1:7.0
	15–20	85	0.12	0.88	0.025	1,956	1:8.0
Growing fat swine	2–3	50	0.38	1.50		3,497	1:4.0
	3–5	100	0.50	2.50		5,580	1:5.0
	5–6	125	0.54	2.96		6,510	1:5.5
	6–8	170	0.58	3.47		7,533	1:6.0
	8–12	250	0.62	4.05		8,686	1:6.3

APPENDIX H

GLOSSARY

Abdomen. That part of an animal's body containing the digestive organs; the part of an insect lying behind the thorax.

Acid. A sour substance, such as vinegar, and lemon juice.

Æsthetic. Appealing to the faculties of taste, as in form, color, etc.

Agriculture. Farming.

Agronomy. Of, or pertaining to, field crops.

Air-dry. Dried in air at ordinary temperatures.

Albumin. A substance found in plants and animals, rich in nitrogen. The white of an egg is a good example.

Alga. A green plant of simple structure, such as pond scum.

Ameliorate. To improve; make better.

Amendment. Substances which improve the productiveness of soils without being used directly as a plant food.

Ammonia. A compound of nitrogen readily usable as plant food.

Animal Husbandry. Raising and caring for animals.

Annual. A plant that bears seed during the first year of its existence and then dies.

Anther. The part of a stamen that bears the pollen.

Antiseptic. Substances which kill germs or microbes.

Art. The skillful and systematic arrangement or adaptation of means for the attainment of some end.

Ash. The mineral substance left when plant or animal substances are burned.

Assimilation. The absorption of digested nutrients into the body substance. Also sometimes used as synonymous with carbon assimilation.

Atmospheric Nitrogen. Free nitrogen of the air.

Available. Said of fertilizing mineral nutrients in the soil when they are in a condition to be absorbed.

Axils. Angle above the junction of a leaf-stalk with the parent stem.

Babcock Tester. Instrument used for determining the amount of butter-fat in milk.

Bacteria. A name applied to a class of very small parasitic plants. There are many kinds, most of which are beneficial to man. Some species are the cause of disease in man and the higher animals or plants.

Biennial. A plant that grows during the first year, and forms seeds, and dies the year following, such as turnips, beets.

Bioplasm. The living substance of cells. See Protoplasm.

Blight. A diseased condition of plants in which the entire plant or some part withers and dries up.

Bordeaux Mixture. A mixture of lime and copper sulphate (bluestone), used to prevent fungus diseases on plants. It takes its name from Bordeaux, France, where it was first used.

Botany. The science that deals with plants.

Breeding. Plant-breeding; animal-breeding. The practice of selecting out the best individuals for propagation.

Bud (noun). An undeveloped branch.

Bud (verb). To insert a bud, as in the practice of budding.

Bud Variation. Where a bud produces a branch that possesses characteristics different from the parent plant. New forms originating in this way are called **sports.**

Bulb. A stem with thickened leaves overlapping one another, as in the onion, Easter lily, etc.

Calcareous. Limy, or having the properties of lime.

Calcium. A chemical element giving limestone its distinctive properties.

Callus. The growth of extra tissue over cut or wounded places on plants.

Calyx. The outermost circle of leaves in a flower.

Cambium. The growing layer of cells lying between the bark and the wood.

Cannon. The shank bone above the fetlock in the fore and hind legs of the horse.

Capillary.

Capillarity.

Carbon. The principal chemical element in plants. Charcoal and graphite are forms.

Carbon Assimilation. The process carried on in the cells of green plants in assimilating the carbon of the carbon dioxid of the air.

Carbon Dioxid. A gas formed whenever substances containing carbon are burned.

Carbon Bisulphide. A chemical compound of carbon and sulphur. A heavy inflammable liquid used to kill insects in stored grain.

Carbohydrate., Compound of carbon with water, such as sugar, starch, wood fiber, etc. They form the largest part of plant substance.

Carnivorous. Feeding on flesh.

Casein. Milk curd, the most important albuminoid in milk and cheese.

Catch Crop. A crop grown during an interval between harvest of regular crops.

Cellulose. The principal carbohydrate in wood fibers, such as cotton, flax, wood pulp.

Cereal. The name given to the grasses cultivated for their grain, as corn, wheat, kaffir corn.

Chemistry. The science that deals with the properties of the elements and their compounds.

Chlorophyll. The green coloring-matter to which plants owe their characteristic color.

Cion. A part of a plant inserted in another with the intention that it shall grow.

Climatology. The knowledge and science of weather. It includes the science of weather (local climate) and meteorology.

Coming True. Reproducing the variety characters.

Compost. Rotted organic matter, plant or animal.

Concentrates. A term used to designate feeding substances that are almost wholly digestible, as corn, bran, mill products.

Contagious. A disease is said to be contagious when it can be carried from one individual to another.

Corolla. The second circle of leaf-like parts of a flower. The corolla is usually colored.

Cotyledons. The primary or seed-leaves of an embryo plant.

Cover Crop. A catch-crop designed to cover the ground during the fall, winter or spring to prevent washing.

Cross. The individual resulting from breeding two varieties together.

Cross-Pollination. The pollination of a flower by pollen from another plant.

Croup (crop). The top of the hips.

Cutting. A part of a stem or root put into the soil or other medium with the intention that it shall grow and make another plant.

Dependent Plants. Plants that do not have the power of making

their own food products; i. e., incapable of carbon assimilation.

Digestion. The process of converting the insoluble substances of foods into soluble materials, preparatory to absorption into the blood.

Drainage. Removing surplus water from the soil, either by ditches, terraces or tiles.

Ecology. The science which treats of the inter-relationships between animals and plants, and their environments. The study of the modes and conditions of life of plants and animals,—a very important phase of agricultural science.

Element. A substance that has only one form of matter. An original form of matter.

Emulsion. A more or less permanent and complete mixture of oils or fats and water. Fresh milk is an excellent illustration.

Endosperm. Reserve food in seeds stored outside of the embryo.

Energy. Power; force. Every movement of, or change of body, expends energy. The energy of sunlight may be expressed in sunlight heat, or other form of energy.

Ensilage. Green foods preserved in a silo.

Entomology. Science of insects.

Erosion. Wearing away. Denudings, as of rocks or soils.

Ether Extract. A term used in feed analyses to describe the substances removed by ether—usually oils.

Evolution. The doctrine that present forms of plants and animals are descended from previous forms. A theory of the origin of forms of living organisms.

Farming. The practice of raising crops and animals.

Farmstead. A farm home or establishment.

Fecundation. The union of male and female cells.

Fermentation. A chemical change produced by bacteria, yeast, etc. Example, souring of milk. The decay of any organic substance is due to a form of fermentation.

Fertilization. Used in the same sense as fecundation.

Fertilizer. A substance added to the soil to improve its productiveness, as compost. Some fertilizers are known as amendments, which see.

Fetlock. The long-haired cushion on the back side of a horse's leg, just above the hoof.

Fiber. Any fine thread-like substance, as the wood fibers of stems, cotton fiber, etc.

Fibro-vascular Bundle. The bundles of wood fibers and water-conducting vessels in the stems and leaves of plants.

Flocculate. To make granular.

Floral Envelope. The collective term for the calyx and corolla.

Fodder. Any coarse dry food for animals.

Forage. Plants fed to animals in their natural condition; i. e., without preparation.

Formalin. A solution in water of the gas known as formaldehyde. It is used to destroy bacteria, fungi, etc.

Function. The particular use of any organ or part.

Fungicide. Substances used to kill fungi, as compounds of copper.

Geology. The science that deals with the formation and properties of the earth.

Germ. See Microörganism; bacteria. Also applied to the embryo of seeds, as in corn.

Germination. To sprout; to grow from a seed.

Girdle. To make a cut or groove around a tree or branch.

Glucose. A kind of sugar, very common in plants. The sugar from grapes is glucose, but the sugar from cane and beets is not. Glucose is formed from starch in the manufacture of syrups.

Gluten. A form of protein found in plants.

Grafting. The practice of inserting a cion into a plant or root that it may grow.

Growth. The increase in size or substance of a plant or animal.

Gypsum. Same as Plaster of Paris.

Herbivorous. Feeding on plants.

Heredity. The resemblance of offspring to parents.

Hibernating. Passing the winter or dormant season in an inactive or torpid state in confined quarters.

Hock. The joint in the hind legs of quadrupeds corresponding to the ankle of man.

Horticulture. Pertaining to the growing of fruits, vegetables, flowers, and other ornamental plants.

Host. The plant or animal upon which a fungus or insect lives.

Humus (or humous). Partly decayed or rotten remains of plants and animals.

Husbandry. Farming.

Hybrid. The progeny resulting from the crossing of two kinds of plants, either varieties or species.

Hydrogen. A chemical element. It is present in water and all living substances.

Hygroscopic. Holding moisture as a film on the surface.

Hypha (plural, hyphae). The separate threads of the plant body of fungi.

Inoculate. To infect with a disease.

Inorganic. Matter which has not been elaborated into plant or animal substance.

Insectivorous. Eating insects.

Insecticide. A poison used to kill insects.

Internode. The space between two nodes of a stem.

Inter-tillage. Tillage between plants.

Kainit. A salt of potash used in making fertilizers.

Kernel. A single seed, as a grain of corn, wheat, etc.

Kerosene Emulsion. See Appendix B.

Larva (plural, larvæ). The worm-like stage in the development of insects.

Layer. A part of a plant that has been bent down and covered with soil to stimulate the formation of roots. After the roots are formed, it is separated from the parent plant.

Legume. A plant belonging to the same family of plants as the pea, bean, alfalfa, clovers, etc.

Lichen. A kind of fungus plant that grows associated with algæ. Very common on stones and bark of trees.

Loam. An earthy mixture of sand and clay, with some organic matter.

Magnesia. A substance containing the chemical element magnesium. It is similar to lime.

Microbe. A general term applied to all plants or animals that are so small that they may be seen only by aid of the microscope.

Mildew. A cobwebby fungus on the surface of diseased or decaying things.

Mold, or Mould. Used in the same way. Mold occurs only on dead substances.

Mulch. A loose covering of straw, leaves, or soil, to retard evaporation from the soil.

Nitrate. A compound having NO_3 combined with a basic mineral substance; a salt of nitric acid.

Nitrification. The changing of nitrogen into nitrates.

Nitrogen. A gaseous chemical element composing 79 per cent of the

air. It forms a constituent of the more expensive mineral plant-foods. A constituent of ammonia, albumen, proteids and all living substances.

Node. The place on a stem where the leaves and branches originate.

Nutrient. A substance which serves as a food.

Organic. Of or belonging to living things. Organic matter has been formed from simple chemical compounds and exist in nature only as formed by animals or plants.

Osmosis. The movement of a liquid through a membrane.

Ovary. The part of the pistil that bears the seeds.

Ovule. The parts inside of the ovary that grow into seeds.

Ornithology. Science of birds.

Oxygen. A gaseous element composing about one-fifth of the air.

Oxidation. Combining with oxygen, as in the rusting of iron, burning of wood.

Parasite. Dependent plants or animals drawing their food from other living plants or animals. Compare with Saprophyte.

Pedigree. A record of one's ancestors.

Perennial. Plants that live from year to year, as trees.

Petal. Parts of the corolla of flowers.

Phloem. That part of a stem through which the reserve food moves. In plants with netted veined leaves it is just outside of the cambium.

Phosphate. A salt of phosphoric acid. The bones of animals and the shells of oysters are composed of phosphates.

Photosynthesis. Same as Carbon Assimilation.

Physiology. The science that treats of the life processes. It treats of organs and their uses.

Pistil. The part of a flower containing the embryo seeds.

Plumule. The shoot end of an embryo plant.

Pollination. The act of carrying pollen from anther to stigma. It is usually done by the wind or insects.

Pollen. The powdery mass borne by anthers. It is necessary for the formation of seeds.

Potash. A substance containing potassium.

Predaceous. Living by preying, or pillaging. Said of insects that attack and destroy other kinds.

Protoplasm. The living substance. "The physical basis of life."

Proteids. Organic substances rich in nitrogen.

Ration. A daily allowance of food for an animal.

Rotation (of crops). A systematic order of succession of crops on the same land.

Roughage. Dry, coarse fodders.

Sap. The watery solutions in plants.

Saprophyte. Living on dead organic matter.

Scion. A shoot, sprout or branch taken to graft onto another plant.

Science. "Systematized common sense." Knowledge gained and verified by exact observation and correct thinking. KNOWLEDGE deals with simple facts, without reference to inter-relations. ART refers to something to be done. SCIENCE to something to be known.

Sepals. The segments of the calyx.

Silage. Green feed cut up and preserved without loss of succulence.

Silo. A place for keeping silage.

Smut. A term to designate the fungi that produce the blasting of the fruits and leaves of plants.

Soil. That part of the earth's crust permeated by the roots of plants.

Soiling. The practice of feeding green plants in the stables.

Spiracle. Breathing pores of an insect's body.

Spore. The one-celled reproductive body of the lower plants.

Sport. A marked variation from the parents that appears suddenly.

Stamen. The part of a flower bearing the anthers with pollen.

Starch. A carbohydrate found in plants.

Sterilize. To destroy all the germs or spores in or on anything.

Sterile Plants. Plants that do not set seed.

Stigma. The part of a pistil that receives the pollen.

Stover.

Stoma (plural, stomata). The minute openings in the epidermis of leaves.

Subsoil. The layer of soil below the surface layer of cultivated soils.

Superphosphate. Phosphates that have been treated with sulphuric acid to render the phosphates available.

Thorax. The middle part of an insect's body.

Tillage. The act of preparing the ground to receive the seed and the cultivation of the plants.

Tuber. A thickened underground stem, as an Irish potato.

Tubercle. A small wart-like growth on the roots of legumes, caused by the nitrogen-fixing bacteria.

Variety. A kind or sort of plant.

Viable. Capable of germinating. Having life.

Vigor. Referring to the rapidity of growth, without reference to hardiness.

Vital. Of, or pertaining to living things.

Water-Table. The line of free water in the soil.

Weathering. The action of moisture, air, frost, upon rocks, etc.

Weed. A plant where it is not wanted.

Wilt. Used synonymous with blight.

Zoölogy. The science that treats of animals.

INDEX